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GUIDELINES FOR QUALITY ASSURANCE PROGRAMS FOR MOBILE SOURCE EMISSIONS MEASUREMENT SYSTEMS. PHASE II. HEAVY-DUTY DIESEL ENGINES - TEST PROCEDURES

Rod Pilkington, et al

Olson Laboratories, Incorporated
Anaheim, California

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16. ABSTRACT

Test Procedures for Heavy-Duty Diesel Engines Mobile Source Emissions Measurement Systems are presented with the concept of a total Quality Assurance System. The Test Procedures are presented in document control format and give the detailed test procedures with Quality Assurance provisions for each part of the total testing system.

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GUIDELINES FOR QUALITY ASSURANCE PROGRAMS FOR MOBILE SOURCE EMISSIONS MEASUREMENT SYSTEMS:

PHASE II, HEAVY-DUTY DIESEL ENGINES - TEST PROCEDURES

by

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June 1975

EPA REVIEW NOTICE

This volume has been prepared by Olson Laboratories, Incorporated consistent with the Environmental Protection Agency Quality Assurance principles and concepts and with the Environmental Protection Agency Mobile Source Testing Practices at Ann Arbor, Michigan.

The guidelines and procedures are generally applicable to mobile source testing operations and are intended for use by those engaged in such measurement programs

It is requested that recipients and users of this document submit any comments and suggestions to the Project Officers.

Mention of trade names or commercial products does not constitute Environmental Protection Agency endorsement or recommendation for use.

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INTRODUCTION

The test procedures contained in this volume are a documentation of the 1975 heavy-duty diesel emission measurement test requirements presently in use at the Ann Arbor facility of the Environmental Protection Agency. These test procedures comply with Federal Regulations as stated in the Federal Register, (Subparts I and J), Section 3, Volume I, for the listing of applicable Federal Registers.

Section 5, Volume I, outlines the development of an Operations manual which may be used as a guideline for a Quality Assurance program. A typical format of a test procedures manual is described and offers a guide for implementing and interpreting the test procedures contained in Volume II. A user may accept the manual in its presented form, or may modify the format to suit specific contractual obligations, or delete certain procedures which may not be performed at that facility. The user will be required to make revisions as needed to assure that the manual complies with Federal Regulations. Revisions may be implemented manually, by computer updates or by magnetic card storage.

For ease of use, the test procedures are separated into nine distinct sections, numbered 100-900. The table of contents shows the major heading of each section and the test procedures contained in each. To differentiate between the light-duty and heavy-duty testing which are both included in this contract, the test procedures are numbered to correspond to Light Duty, 101-149, 201-249, etc. and Heavy Duty, 150-199, 250-299, etc. Heavy-duty diesel procedures modified for use with heavy-duty gasoline engines are suffixed with a -G, e.g.TP-750-G. Certain procedures developed for Phase I (Light-Duty Gasoline Vehicles) are equally applicable to Phase II (Heavy-Duty Diesel Engines) and have been included in this volume, utilizing the original Test Procedure reference number allocated for Phase I.

To assist in defining the overall scope of the heavy-duty testing program, the tables from Section 3, Volume I, briefly outlining the test procedures, specifications, and quality provisions are included in the introduction to the test procedures manual.

This document details test procedures for heavy-duty diesel engines, and a supplement will cover test procedures for heavy-duty gasoline engines (Phase IV). The test procedures for light-duty diesel engines (Phase III) will appear as a supplement to the light-duty gasoline vehicle procedures detailed in Phase I, Volume II.

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FEDERAL EMISSION TEST PROCEDURE - SMOKE AND GASEOUS EMISSIONS

[illegible] TASK	BASIC DESCRIPTION	FR REF EPA TP NO.	SPECIFICATION OR TOLERANCE-FED. REG.	SPECIFICATION- SAE OR [illegible]	QUALITY PROVISIONS	TEST INVALID	CORRECTIVE ACTION	TRAINING OR SKILL LEVEL
A. Engine-Dyno Preparation	The engine is installed on the test bed and coupled to the dyno. Auxiliary equipment, exhaust and inlet air systems are installed on the engine.	85.874-12 85.974-12 TP-750	Exhaust system shall be 12 ±5 ft. from manifold or VEE. Backpressure = ±1.2" Hg of Mfr. Spec. @ Max. hp. Inlet restriction ±1" H_2O of Mfr. Spec. @ Max. Air flow. Final 2 ft. straight and round dia. determined by hp.	MCAPC Advisory Circular No. [illegible], shipping instructions and preparation of heavy duty engines for EPA testing	Installation checked by supervisor prior to engine start up. Inlet and outlet P. recorded and checked by data validation.	Improper installation resulting in out of tol. restriction. Incorrect Mfr. spec. used.	Correct installation and repeat test. Determine correct specifications.	Heavy duty engine mechanic with knowledge of dyno operation and installation procedures
B. Engine Dyno Checkout	The engine is operated at idle and load conditions to check for proper operation, make final adjustment and determine that engine speed, torque and fuel flow meet Mfr. specifications.	85.874-16(b) TP-750	Adjustments must be completed in less than 1 hour running time for zero hour test.	Listen for internal noises, such as piston slap, knocks, tap and gear noises that indicate irregularities in engine operation.	Preliminary checkout of engine parameters and associated measurement devices such as torque, speed, T&P fuel flow meters.	Engine irreg. detected. Inability to achieve proper inlet and/or outlet restrictions Mfr. Spec. not achieved by engine or dyno.	Shut down engine and notify supervisor and Mfr. Rep. Determine restriction problem and correct.	Engine dyno operator with working knowledge of heavy duty engine operations and performance.
C. Engine test cycle preconditioning	Engine is operated at maximum rated horsepower for 10 min. or until temperature and oil pressure reach equilibrium	85.874-9 85.874-16 TP-751	Inlet Air 68-86°F Bar 28.5-31 in. Hg for preconditioning - Test governor and fuel system adjusted to Mfr. Spec.		Final equipment check before test start.	Engine not fully warmed prior to start of test.	Repeat test	As above in B
D. Smoke measurement and test cycle	The warm engine is run through three sequences of idle, acceleration, and lugging modes.	85.874-9 85.874-16 TP-751	Idle time 5-5.5 min. accel. 200 ±50 rpm above idle for 35 sec. Accel. to 85-90% rated speed in 5 ±1.5 sec. Accel. shall be linear ±100 rpm. Lugging ±50 rpm of specified speed.	Test cycle repeated until 3 consecutive valid tests have been achieved. Opacity filters checked by EPA every 6 months.	Smoke meter calib. traceable to NBS. All test data checked by data validation	Incorrect time, load or speed. Excessive Instrument drift.	Repeat test Correct inst. problem.	As above with smokemeter experience or training.
E. Intake air measurement	In order to determine emissions on a mass basis, the mass of intake air must be measured as a function of time for each mode of the gaseous cycle.	85.974-13(c) TP-752	SAE recommended practice J244	△ P accuracy of 0.5 percent of idle flow. Leakage test to within ±0.5 percent of idle flow.	Leak check of air measurement system. LFE calibration traceable to NBS. Transducers calibrated against manometer before and after test.	Leaks on change in △P. read out calibration will invalidate test.	Correct problem and rerun test	Training in use and installation of LFE and manometers.
F. Measurement of Fuel Flow	In order to determine the total mass of the exhaust, the mass of fuel must be measured per unit time. Mass Ex = Mass Air + Mass Fuel.	85.974-14(m) TP-755 TP-756	SAE J244 SAE J816b Fuel temperature must be 100 ±10°F at pump inlet	±1 percent of observed reading.	Data checked by validation - fuel temp and mass flow. Flowmeter calibrated with dead weight tester.	Failure to record fuel flow during any mode. Flowmeter malfunction detected.	Repeat test	Instruction in operation of fuel flow meter.
G. Gaseous Emission test cycle	The test is designed to determine the brake specific emissions of hydrocarbons, carbon monoxide and oxides of nitrogen when an engine is operated through a cycle which consists of three idle modes and five power modes at each of two speeds which span the typical operating range of diesel engines.	85.974-9,11,16 TP-753	Speed ±50 rpm Torque ±2 percent of the max. torque and the test speed. Warmup for 10 min. or equil. T&P at rated speed and and max. hp. Operate 10 min. each mode. (See C. Preconditioning.) RPM and torque changes in first minute. Torque and rpm spec. must be met during last min. of mode. Fuel type 1-D or 2-D.	SAE J1243	If a delay of more than 10 min. occurs repeat test from mode 1. Time, rpm, torque checked by data validation.	Mode time in excess of 10 minutes, rpm, torque or time out of tolerance.	Repeat test from mode 1.	Instruction in operation of dyno controls.
H. Measurement of HC, CO, NO and O_2 in diesel exhaust	Measurements are made of the exhaust concentrations during the last minute of each mode. O_2 is measured only if required for correction of the HFID reading	85.974-13,15,16 TP-753 TP-754	SAE J177 Sect. 2.1, 2.2, 2.3.3 SAE J215 Sect. 2.1, 2.2, 3 and 7 Auxiliary instruments calibrated according to good practice. Instrument zeros checked as necessary to maintain test validity. Zero and span at start, mode No. 7, end of test. Record analyzer response during 10 min. test, sample last 5 min. of test.	Calibrate monthly, 5-point calib. ±2 percent, weekly checks. 2 hr. min. warmup. Span 75-95 percent. Sample dryer. HC range 10-4,000 ppm response 90 percent - [illegible] sec. Detector and oven temp. cont. ±[illegible]. Range 150-200°F. Probe - multi-hole, 80 percent across exhaust pipe, heated sample line 150-200°F ±2% of set point.	Optimize detector response. Weekly O_2 interference check. Optimize system operating temperature. H_2O, CO, interference check. monthly. Data validation.	Span or zero shift. Incorrect sample time. Incorrect span deflection. Inadequate or too low temp. cont. Calib. overdue	Correct span and zero shift and repeat from last check point. Repeat test cycle as required. After correcting out-of-spec. condition.	Training in operation of analytical console. Knowledge of calib. maint. and minor adj. of instruments.
I. Data collection and reduction	For complete list of required information see 85.974-15. Ambient condition fuel and air flow, analyzer output are recorded/validated and the data reported in grams per brake horsepower	85.974-16,17,18 TP-751, 752, 753, 754, 755, 756, and 851	RPM/Torque/intake air/restriction exh. and air/fuel flow/air flow, recorded during last 1 min. each mode. Fuel flow during idle and 2 percent may be measured following or prior to running cycle. Analyzer response integrated for last 60 seconds of each mode. Correct NO_x for humidity. Weighting factor Idle [illegible], other modes [illegible]	Mass flow rate SAE J244. Mass ex = Mass air + mass fuel Correct sample. Conc. to wet basis SAE J177	Data validation check computer - inst. output alignment each test. Sample transport time checked each test.	Detection of error or abnormality at this point requires invalidation of test.	Repeat complete test sequence	Training in data validation, chart reading, data inspection, and reduction, computer operation as required.

Section 100

GAS BLENDING, FUEL ANALYSIS AND INVENTORY

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EPA TEST PROCEDURE	Number TP-101	Page 1 of 10

SUBJECT PREPARATION OF GRAVIMETRIC BINARY GAS MIXTURES	
Reference C. D. PAULSELL DRAFT 8/1/73	Data Form No. 101-01, 02
Responsible Organization CHEMICAL ANALYSIS	Computer Program CYLBLEND
Test Witness QUALITY ASSURANCE REVIEW/REQUESTOR	Performance Interval AS REQUESTED
Type of Test Report GAS BLEND DATA SHEET	Supersedes NEW
Report Distribution QUAL. ASSUR., CORR. & MAINT., INST. SERV.	Superseded by

REMARKS/COMMENTS

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REVISIONS

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1.0 PURPOSE

This procedure outlines the equipment, blending process, and calculations necessary to generate binary gravimetric gas mixtures to be used as primary standards. The gravimetric technique is considered to be the most accurate method for the quantification of gases. Since the final data reported for emission measurement is in mass units it is of great importance that the primary standards be determined by mass rather than pressure or volumetric relationships.

2.0 TEST ARTICLE DESCRIPTION

Binary mixtures are prepared from pure components or blending mixtures of propane (C_3H_8), carbon monoxide (CO), carbon dioxide (CO_2) and nitric oxide (NO). Dilution of these gases is done with pure nitrogen or air.

3.0 REFERENCES

3.1 Procedure For Making Gravimetric Binary Gas Mixtures. EPA, C.D. Paulsell, 8/1/73.

3.2 Matheson Gas Data Book

3.3 "The Present State of The Art In The Preparation of Gaseous Standards", Scientific Gas Products, Inc.

3.4 "Handbook of Compressed Gases", Compressed Gas Assoc., Inc. Reinhold Publishing Corp., New York, N.Y.

4.0 REQUIRED EQUIPMENT

4.1	Cylinders:	Marison 1CC3AA1800 Carbon Steel 5.25" O.D. x 13.75" Length Volume - 223 Cubic Inches
		Stainless Steel NO_x Cylinders 3.75" O.D. x 13.0" Length Volume - 110 Cubic inches
4.2	Valves:	Brass, Sherwood Selpac B G-5 3540 F9 CGA350
		Stainless Steel Superior CGA 660SS
4.3	Balance:	Voland Model 1115 CDN 10Kg Capacity 1 Mg Accuracy
4.4	Weights:	2 sets (1 gram to 1 kilogram) Calibration traceable to NBS

4.5 Blending manifold with pressure gauges to cover 0-30, 0-300, and 0-2000 PSIA and (1) vacuum gauge 0-5 PSIA

4.6 Vacuum Pump: 150 liter/min maximum capacity
Ultimate pressure 1 millitorr Hg absolute.

4.7 Pure Gases

- Zero grade Air: 220-300 cubic feet
  2000-2600 P.S.I.G.
  Max. THC 0.1 PPMC
  O_2 19-23% Analyzed

- Zero grade Nitrogen: 220-300 cubic feet
  2200-2600 P.S.I.G.
  Max. THC 0.1 PPMC

- O_2 free nitrogen for NO blend

- Propane - Instrument Grade 99.5% minimum

- Carbon Dioxide - Coleman - 99.8% minimum

- Carbon Monoxide - Ultra high purity - 99.8%
  THC 1 PPMC

- Nitric Oxide, C.P. Grade, 99.0% Min.

5.0 PRECAUTIONS

5.1 Gas blending should be attempted only by qualified personnel familiar with the chemistry of gases and blending equipment operations. Equipment damage, serious injury, or loss of life could occur from deviations from prescribed practices.

5.2 Personnel should be familiar with safe handling of compressed gases

5.3 Avoid sudden surges of gases when blending or transferring. Always "Bleed" gas slowly from one cylinder to another in order to minimize temperature changes.

5.4 Special precautions should be taken when blending combustible gases such as propane and CO with air. Only very low concentrations should be attempted i.e., less than 1000 PPM.

5.5 Attach only the diluent being used to the blending manifold (air or nitrogen).

5.6 All traces of combustible material such as oil, grease, and solvents shall be removed from the gauges, fittings, valves and tubing contained in the blending manifold. All manifold parts should be specified, "cleaned for oxygen service," when ordered.

5.7 Cylinder valves should be inserted with teflon lubricant only.

5.8 Never drop cylinder or weights onto balance pans or release quickly.

6.0 VISUAL INSPECTION

6.1 Cylinders:

- Check for valve or cylinder damage, especially the threads on the valve.
- Check the cylinder for dirt or other contamination

6.2 Blending Manifold:

- Check all tubing and the cylinder connections for loose or damaged fittings.
- Check gauges for proper atmospheric reading.

6.3 Balance:

- Check for any visual damage.
- Check weights for damage or contamination.

7.0 PREPARATION

7.1 Weights:

Remove all weights from the balance pans and case, dust them carefully and wipe any smears from the weights with a lint free cloth. Do not touch with hands.

The weights should be kept in their box when not in use and should only be handled with the transfer tool provided.

7.2 Balance:

Turn the vernier chain mechanism to zero and release the pans of the balance. Check the action of the pan arrest pads and adjust if necessary to achieve smooth operation. When the pans are stable, the indicator should read null. If it does not, adjust the zero knob to bring the needle to the null position. Arrest and release the pans several times to assure that the balance stabilizes in the null position. The balance point for the loaded pans should be within ±10 mg.

The weights are now ready to be cross checked on the balance to assure accurate determination under loaded conditions. Place the weights in the center of the pans as indicated below and note any deviations.

Left Pan	Right Pan
0	0
1	Vernier
1, 2	3
2, 3	5
2, 3, 5	10
2, 3, 5, 10	20
10, 20	30
20, 30, 2	50, 1, Vernier
20, 30, 50	100
0	0
20, 30, 50, 100	200
100, 200	300
200, 300	500
200, 300, 500	1000
0	0

7.3 Cylinders:

New cylinders or cylinders which have been recently revalved should be checked for leaks by pressurizing to 1800 PSIG with nitrogen. Some leaks are not apparent until the cylinder has reached its maximum pressure distortion. Check for leaks with "Snoop" or other device which will not leave a residue on the cylinder. Check valve stem, relief device and cylinder threads. Note results in cylinder log. Correct leaks if possible. If valve is leaking at the cylinder threads, the valve must be removed and reinserted. Do not attempt to tighten valve.

Cylinders which have previously been used for mixtures should be flushed with the diluent (air or nitrogen) as follows:

- Vent cylinder contents slowly in the hood being certain the hood blower is operating.
- Evacuate to 1.0 PSIA.
- Fill to 15 PSIG (30 PSIA) with diluent to be used.
- Vent the contents and evacuate. Repeat this purge to final evacuation 0.2 PSIA.
- Confirm that cylinder pressure is less than 0.2 PSIA.
- Close cylinder valve firmly and proceed to the blending procedure.

7.4 Blending Manifold:

With all vents closed on the manifold, pressurize all gauges to 25 PSIA and close off the manifold. Check all gauges for correlation and observe the readings for indicating leakage. Find and correct any leakage. This is especially important in preparation of NO blends. Small oxygen leaks will oxidize the NO to NO_2 and this can occur at manifold pressures above atmospheric. Leakage of the NO gas should be avoided because of its toxicity and transfer should be performed in a hood or well ventilated area.

8.0 TEST PROCEDURE

The preparation of gravimetric gas mixtures basically involves two procedures, blending and weighing. Blends are made according to the information contained on Form No. 101-01. This form must accompany the work order and be completed by the requestor. Refer to Reference 3.1 for calculation procedures. Test data is entered on Form No. 101-02.

Test Sequence	Test Description	Data Output
	Parent Blend Made From Pure Component	
101	Evacuate and purge with diluent (N_2 or Air, whichever will be used in the mixture) twice and then evacuate the cylinder to 0.2 PSIA. Close the cylinder valve and remove the vacuum line.	None
102	Wipe cylinder to remove the dust and place on the left pan of the balance.	Record cylinder number
103	Place a similar type cylinder on the right pan to compensate for buoyancy. This same cylinder must be used for all subsequent weight determinations. Record cylinder number in blending log book.	Log Book Entry
104	Add weights to right pan until null indicator shows a deflection. This will indicate that the null is within 1 gram of the weight. NOTE: If the blending cylinder should weigh less than the tare cylinder a weight must be added to the left pan. Do not remove this weight until all weighings have been completed.	None
105	Close balance door and obtain final null with vernier chain. Record sum of wts. on right balance and null vernier indicator weight. Secure and release pans to assure zero null.	Cylinder Weight Grams
106	Attach the cylinder to the minor component regulators. (This line should be equipped with a flow control valve.) Purge the line with the minor component up to the empty cylinder valve.	

Test Sequence	Test Description	Data Output
107	Set the regulator on the minor component to the pressure indicated under column shown P_1 PSIG on form 101-01. If pressure is less than atmospheric the blending manifold must be used and cylinder is filled using the pressure indicated under PSIA.	
108	With the flow control valve closed, open the cylinder valve. Bleed in the desired amount of pure component. If above atmospheric allow the cylinder to attain equilibrium with the regulated pressure.	
109	Close the cylinder valve, and shut off minor component. NOTE: To achieve 0.1% accuracy always add at least 5 grams of minor components. Reweigh the cylinder as in Sequence 102-105.	Weight after adding minor component
110	The cylinder is now ready for the addition of diluent. The cylinder is attached to the gauge manifold and the lines are purged with diluent up to the CGA fitting. When the 0-2000 PSIA gauge reaches a pressure higher than that of the cylinder (200 PSI), open the cylinder valve and fill it by regulating the diluent in 100 PSIA increment. Close the cylinder valve when the pressure gauge needle moves past the desired final pressure. The final pressure should be approximately 3% final pressure higher than desired to makeup for the pressure loss due to the cylinder cooling.	None
111	Shut off the diluent source and bleed the manifold before disconnecting the cylinder. Reweigh the cylinder as in sequence 102-105 after the cylinder has reached ambient temperature.	Weight after adding Major Comp.Grams
112	Record the three weights and submit the data for computation of mass ratio, concentration, and final pressure.	Initial Minor Final

REVISIONS:

PREPARATION OF GRAVIMETRIC BINARY GAS MIXTURES

TEST PROCEDURE

PROCEDURE NO. TP-101

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Test Sequence	Test Description	Data Output
113	The parent blend should be mixed thermally for 1/2 hour by directing a heat lamp from a distance of 18-24 inches at the bottom of the cylinder which has been tilted 45° with the horizontal.	
114	If a dilution of the parent mixture is to be made, the same procedure is used except that the parent blend can be added to the empty cylinder by using a well purged regulator to obtain the approximate pressure needed to achieve the final concentration desired.	

9.0 DATA INPUT

Form 101-02 requires the following:

Blending Date
Components
Operators Initials
Cylinder Numbers
Cylinder weights (3) Initial, Minor, Final
Comments

10.0 DATA ANALYSIS

10.1 Submit data for analysis by "CYLBLEND" computer program.

11.0 DATA OUTPUT

11.1 Computer print out showing calculated mass ratio concentration. Forward with complete job request to requestor.

11.2 Compare specified value with calculated value. Check final cylinder pressure.

11.3 Check computer entries against original data form.

11.4 If cylinder was previously used, check to see that it has been deleted from the inventory list.

12.0 ACCEPTANCE CRITERIA

12.1 Calculated values should agree with specified within ±5%. If not determine cause and if final concentration is acceptable, correct and report the errors or failures.

13.0 QUALITY PROVISIONS

13.1 See Section 7.2 balance check.

13.2 NBS certified weights are used to check the working weights at six month intervals.

13.3 Gases used for blending are checked for purity when received from supplier.

GRAVIMETRIC GAS BLENDS

SPECIFICATION DATA

NOMINAL CONCENTRATION	COMP. $\frac{\text{MINOR}}{\text{MAJOR}}$	MINOR BLEND REQ'D.	PRESS. P_1 PSIG	PRESS. P_1 PSIA	APPROX. M_1 GRAMS		PRESS. P_2 PSIA	APPROX. M_2 GRAMS	MARISON CYL. SERIAL NO. USED

FORM 101-01

GRAVIMETRIC GAS BLENDS
INPUT DATA SHEET

BLENDING DATE	COMPONENTS MINOR	COMPONENTS MAJOR	BLENDERS INITIALS
- -			

5 10 15 20

COMPONENT SYMBOLS

MINORS	C_3H_8	- PROPANE	(99.5%.MIN.)
	CO	- CARBON MONOXIDE	"
	CO_2	- CARBON DIOXIDE	"
	NO	- NITRIC OXIDE	"
	CH_4	- METHANE	"
MAJORS	AIR	- ZERO GRADE AIR	
	N_2	- ULTRA PURE NITROGEN	

BLEND NO.	CYLINDER NUMBERS		CYLINDER WEIGHTS (GRAMS)			
	NEW BLEND 4	PARENT BLEND 12	INITIAL (EMPTY) 21	AFTER ADDING MINOR 29	AFTER ADDING MAJOR 37	COMMENTS: 44
1	-	-	.	.	.	
2	-	-	.	.	.	
3	-	-	.	.	.	
4	-	-	.	.	.	
5	-	-	.	.	.	
6	-	-	.	.	.	
7	-	-	.	.	.	
8	-	-	.	.	.	

5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80

NOTES: TWO SPECIAL PARENT CYLINDER NUMBERS ARE RECOGNIZED.
" -PURE " INDICATES A PARENT BLEND HAS BEEN MADE FROM PURE COMPONENTS.
" -VENT " INDICATES THAT THE CYLINDER REFERENCED HAS BEEN VENTED AND IS TO BE DELETED FROM THE FILE OF CYLINDERS.

MTS COMMAND:
```
$ RUN SAQF: CYLBLEND. [SCARDS = *SOURCE*] [SPRINT = *SINK*]
```
DATA SETS MUST BE SEPARATED BY A SINGLE $ ENDFILE CARD.
TOTAL RUN TERMINATES ON TWO $ ENDFILE CARDS.

Form 101-02

TP-101
Attachment No. 1

EPA STANDARDS INVENTORY

GRAVIMETRIC GAS BLENDS

Propane in Air

3 ppm *
5 ppm
10 ppm *
15 ppm
25 ppm
50 ppm *
75 ppm
100 ppm *
150 ppm
200 ppm
275 ppm
350 ppm
500 ppm *
1000 ppm

Methane in Air

3 ppm
10 ppm
25 ppm
50 ppm
75 ppm
100 ppm
300 ppm
1000 ppm
20000 ppm P/N_2

Propane in N_2

100 ppm
200 ppm
400 ppm
600 ppm
800 ppm
1000 ppm
2000 ppm
3000 ppm
4000 ppm
6000 ppm
8000 ppm
10000 ppm P
15000 ppm
20000 ppm

CO in N_2

5 ppm
10 ppm
25 ppm
50 ppm*
100 ppm*
150 ppm
200 ppm
250 ppm
500 ppm*
750 ppm
1000 ppm*
1250 ppm
1500 ppm
2000 ppm
2500 ppm
3000 ppm
4000 ppm
0.5%
1.0%
1.5% P
2.5%
5.0%
7.5%
10.0%

CO_2 in N_2

0.2%
0.4%
0.6%
0.8%
1.0%*
1.5%
2.0%
2.5%
3.0%
4.0%
5.0%
7.0%
9.0%
11.0%
13.0%
15.0%*

NO in N_2

25 ppm
50 ppm *
75 ppm
100 ppm *
250 ppm *
500 ppm *
750 ppm
1000 ppm *
1500 ppm
2000 ppm
5000 ppm
20000 ppm

NOTE: The concentrations shown here are the nominal values (+0,-10%) which are to be generated, inventoried, and maintained as gravimetric standards.

SYMBOLS: P = Parent Blend
* = NBS Standard

Revision Date

TP-101
Attachment No. 2

```
                *** GRAVIMETRIC GAS BLEND ANALYSIS ***

                DATE: 05-11-74      MINOR COMPONENT: CO
             BLENDER: JK            MAJOR COMPONENT: N2

MEASURED DATA:

                                        MEASURED CYLINDER WEIGHTS:
                  PARENT
CYLINDER NO.   CYLINDER NO.        EMPTY        AFTER MINOR    AFTER MAJOR
************   ************     ***********     ***********    ***********
                                  (GRAMS)         (GRAMS)        (GRAMS)

  G-11865         -VENT
  G-11832         -VENT
  G-11832         -PURE            79.095          85.832        430.388

CALCULATED DATA:

                   MINOR             MAJOR          MASS         BLEND       CYL.
CYLINDER NO.       COMP.             COMP.          RATIO        CONC.       PRESS.
************    *********          *********     *********    *********    ********
                (GRAMS CO   )    (GRAMS N2   )                  (PPM)       (PSIA)

  G-11865
  G-11832
  G-11832          6.737            344.556      0.0191777    19181.750     1230.

COMMENTS DATA:

CYLINDER NO.
**********
  G-11865    USED FOR CH4 / C3H8 BLEND
               ***CYLINDER NOT FOUND.
  G-11832    ERROR IN PREVIOUS MASSES
  G-11832    99.5% PURE SCOTT B-354

                    PROCESSED:  08:45.00  MAY 14, 1974
```

TP-101
Attachment No. 3

```
                    *** GRAVIMETRIC GAS BLEND ANALYSIS ***

                    DATE: 05-11-74       MINOR COMPONENT: CO
                  BLENDER:  JK           MAJOR COMPONENT: N2

MEASURED DATA:

                   PARENT                 MEASURED CYLINDER WEIGHTS:
CYLINDER NO.   CYLINDER NO.        EMPTY        AFTER MINOR    AFTER MAJOR
************   ************     ***********     ***********    ***********
                                  (GRAMS)         (GRAMS)        (GRAMS)
  F-01363         -PURE           111.534         115.804        543.439
  F-01364        G-11864          145.703         215.915        512.363
  F-01366        G-11864          127.413         196.903        402.777
  F-01367        G-11832          117.401         196.591        402.762
  F-01369         -PURE            10.725          20.449        388.788
  F-01370         -PURE            74.364          93.592        458.242
  F-01372         -PURE            63.287          90.777        444.509
  F-01374         -PURE            98.023         136.893        474.774
              ***MORE THAN 8 DATA CARDS.

CALCULATED DATA:

               MINOR             MAJOR          MASS          BLEND         CYL.
CYLINDER NO.  COMP.              COMP.          RATIO         CONC.        PRESS.
************ *********         *********      *********     *********     ********
             (GRAMS CO  )    (GRAMS N2  )                    (PPM)        (PSIA)
  F-01363       4.270           427.635     0.0098864      9888.500        1512.
  F-01364      70.212           296.448     0.0031751      3175.768        1223.
  F-01366      69.490           205.874     0.0041843      4185.219         964.
  F-01367      79.190           206.171     0.0053221      5323.184         999.
  F-01369       9.724           368.339     0.0257206     25725.941        1323.
  F-01370      19.226           364.650     0.0500889     50099.020        1344.
  F-01372      27.490           353.732     0.0721102     72124.563        1334.
  F-01374      38.870           337.881     0.1031716    103191.375        1319.

COMMENTS DATA:

CYLINDER NO.
************
  F-01363     SCOTT 8582
  F-01364
  F-01366
  F-01367
  F-01369     SCOTT 8582
  F-01370     SCOTT 8582
  F-01372     SCOTT 8582
  F-01374     SCOTT 8582

                     PROCESSED:  08:45.00  MAY 14, 1974
```

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CYLINDER MASS RATIO MAJOR DILUTANT CONCENTRATION PRESSURE BLENDING DATE
******** ********** ***** ******** ************* ******** ************

F-01374    1.0317E-01  CO    N2      103191.375     1319.   05-11-74
F-01372    7.2110E-02  CO    N2       72124.563     1334.   05-11-74
F-01370    5.0089E-02  CO    N2       50099.020     1344.   05-11-74
F-01369    2.5721E-02  CO    N2       25725.941     1323.   05-11-74
G-11832    1.9174E-02  CO    N2       19181.750     1230.   05-11-74
G-11842    1.6698E-02  CO    N2       16701.809     1494.   12-10-73
G-11871    1.6635E-02  CO    N2       16638.902     1505.   01-16-74
G-11864    1.6581E-02  CO    N2       16584.137     1534.   01-16-74
H-89471    1.6204E-02  CO    N2       16207.551     1526.   01-16-74
F-01363    9.8864E-03  CO    N2        9888.500     1512.   05-11-74
F-01367    5.3221E-03  CO    N2        5323.184      999.   05-11-74
F-01366    4.1843E-03  CO    N2        4185.219      964.   05-11-74
F-01364    3.1751E-03  CO    N2        3175.788     1283.   05-11-74
H-89456    2.8147E-03  CO    N2        2815.347     1595.   08-25-73
G-11841    2.4125E-03  CO    N2        2413.045     1547.   04-13-73
G-11833    1.8365E-03  CO    N2        1836.925     1512.   04-13-73
G-11831    1.4102E-03  CO    N2        1410.503     1565.   04-13-73
G-11849    1.2273E-03  CO    N2        1227.580     1516.   04-13-73
G-11829    9.9960E-04  CO    N2         999.817     1424.   04-13-73
G-11863    9.0102E-04  CO    N2         901.215     1443.   11-01-73
G-11856    7.0533E-04  CO    N2         705.482     1538.   04-13-73
H-89474    5.2208E-04  CO    N2         522.192     1447.   11-01-73
G-11828    4.8207E-04  CO    N2         482.176     1365.   11-05-73
G-11873    2.5628E-04  CO    N2         256.333     1526.   03-02-73
H-89475    1.9196E-04  CO    N2         192.006     1389.   08-25-73
G-11848    1.2663E-04  CO    N2         126.660     1475.   08-25-73
G-11838    1.0399E-04  CO    N2         104.014     1388.   11-01-73
G-11840    9.0859E-05  CO    N2          90.879     1328.   08-25-73
G-11825    5.0301E-05  CO    N2          50.312     1366.   11-01-73
H-89469    2.9838E-05  CO    N2          29.844     1023.   08-25-73
H-89460    9.1836E-06  CO    N2           9.186     1054.   08-25-73

G-11845    2.2610E-01  CO2   N2          15.682     1799.   09-25-73
G-11839    2.0178E-01  CO2   N2          13.862     1524.   09-25-73
G-11854    1.7216E-01  CO2   N2          11.691     1460.   09-25-73
G-11868    1.2925E-01  CO2   N2           8.635     1590.   09-25-73
G-11850    1.0236E-01  CO2   N2           6.768     1567.   09-25-73
G-11862    7.6649E-02  CO2   N2           5.019     1566.   09-25-73
H-89462    5.7714E-02  CO2   N2           3.753     1400.   09-25-73
G-11853    4.7014E-02  CO2   N2           3.045     1480.   09-25-73
G-11866    3.8004E-02  CO2   N2           2.453     1537.   09-25-73
G-11847    3.0567E-02  CO2   N2           1.968     1539.   09-25-73
G-11858    2.6188E-02  CO2   N2           1.683     1490.   09-25-73
H-89464    1.6787E-02  CO2   N2           1.075     1279.   09-25-73
H-89476    1.6008E-02  CO2   N2           1.025     1120.   02-22-74
G-11870    1.3044E-02  CO2   N2           0.834     1076.   02-22-74
G-11867    9.8799E-03  CO2   N2           0.631     1092.   02-21-74
H-89465    9.7052E-03  CO2   N2           0.620     1584.   09-25-73
G-11851    6.6281E-03  CO2   N2           0.423     1118.   02-21-74
G-11843    3.6106E-03  CO2   N2           0.230     1543.   02-21-74

G-11872    1.4404E-02  C3H8  AIR       9472.020      748.   03-02-73
G-11844    1.2420E-02  C3H8  AIR       8161.988     1435.   03-02-73
G-11837    1.8923E-03  C3H8  AIR       1238.997     1035.   03-02-73
H-89473    1.8520E-03  C3H8  AIR       1212.553     1639.   08-28-73
G-11846    7.0924E-04  C3H8  AIR        464.185     1023.   10-01-73
G-11860    6.5849E-04  C3H8  AIR        430.960     1247.   03-02-73
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G-11861      6.2204E-04   C3H8   AIR          407.102       770.    03-02-73
G-11836      5.0664E-04   C3H8   AIR          331.554      1406.    03-02-73
G-11827      4.1203E-04   C3H8   AIR          269.635      1690.    03-02-73
G-11869      2.8330E-04 . C3H8   AIR          185.388      1005.    03-02-73
H-89470      1.6471E-04   C3H8   AIR          107.778       740.    03-02-73
H-89459      1.5253E-04   C3H8   AIR           99.808      1229.    08-28-73
H-89466      1.1360E-04   C3H8   AIR           74.332      1014.    11-29-73
H-89457      9.4779E-05   C3H8   AIR           62.018      1015.    03-02-73
H-89480      6.7034E-05   C3H8   AIR           43.863      1068.    10-01-73
G-11835      3.7174E-05   C3H8   AIR           24.324      1011.    10-01-73
G-11857      2.2940E-05   C3H8   AIR           15.010      1010.    11-29-73
H-89472      1.3414E-05   C3H8   AIR            8.777      1042.    10-01-73
G-11852      9.5187E-06   C3H8   AIR            6.228      1432.    10-01-73
G-11826      4.6832E-06   C3H8   AIR            3.064      1486.    10-01-73

H-89458      1.6650E-04   C3H8   N2           105.791      1194.    08-28-73

                         PROCESSED:  08:45.05  MAY 14, 1974
```

EPA TEST PROCEDURE

Number TP-102

Page 1 of 9

SUBJECT

Calibration of Gas Mixtures (Gas Analysis)

Reference
FR 85.075-23(a) (4)

Data Form No.
102-01

Responsible Organization
Correlation & Maintenance

Computer Program
CYLANAL

Test Witness /Review
Requestor, Quality Assurance

Performance Interval
See Below

Type of Test Report
Computer Print Out

Supersedes
New

Report Distribution
Purchasing, Correlation & Maintenance

Superseded by

REMARKS/COMMENTS

1. Analysis of calibration gases are performed when the gases are received from a vendor, when requested by a contractor or manufacturer for correlation and traceability reasons and when an in-house gas is suspect for any reason.

ORIGINAL RELEASE APPROVALS

Office	Section	Signature	Date
Program Mgmt.	Quality Assurance		
Administration	Procurement		
Lab. Branch	Supervisor		
Lab. Branch	Support Oper. Supv.		

REVISIONS

Change Letter	Description of Change	Approval	Date

1.0 PURPOSE

To determine gas mixture concentrations by comparing them to known standards used as calibration gases, working gases and, in some cases, zero gases for the EPA laboratory, contractors, manufacturers.

2.0 TEST ARTICLE DESCRIPTION

A gas blend or mixture blend of two or more gases under pressure in a cylinder or other suitable container.

3.0 REFERENCES

3.1 Analytical instrument manuals

3.2 "Handbook of Compressed Gases", Compressed Gas Associaton, Inc., N.Y., N.Y., Reinhold Publishing Corp., Inc., 1966.

4.0 REQUIRED EQUIPMENT

4.1 Primary gas standards, verified, gravimetric, or NBS cylinders. Verified standards must be traceable to the EPA gravimetric standards by not more than one generation. Zero gas, air or nitrogen as required.

4.2 Analytical instruments with the following minimum specifications:

Sensitivity:	Full scale for the concentration to be determined.
Reproducibility:	1% of full scale, for successive identical samples.
Stability:	Electronic stability of ±1% per 24 hours.
Response:	90% of scale in 0.5 seconds.
Dectector Type:	CO, CO_2 - NDIR: HC - FID, NO - CHEMI.

4.3 Sample handling system, manual or automatic, designed for a minimum hook up of 2 span gases, one zero gas and the gas to be analyzed. The system need not be equipped with a sample pump unless required but should have line filters, flow meters and pressure gauges. The materials of construction of the equipment prior to the instrument sample inlet should be of teflon, stainless steel and viton. Use best judgment for the instrument exhaust plumbing and equipment.

4.4 Pressure regulators, dual stage, outlet pressure to be regulated between 0-80 PSIG, inlet pressure rated at 4000 PSI with a gauge 0-3000 PSI. The regulator should be equipped with a purge port and safety relief port. Regulators used for nitrogen oxide or any other corrosive gas should be of stainless steel construction only, the other gases require brass with teflon or viton seals.

NOTE: Some regulators use a Buna N or other rubber type material for construction of the diaphragm. These should never be used for gas analysis for hydrocarbon or the zero gases.

4.5 Recorder to match the output of the analytical instrument.

4.6 Digital volt meter with the capability of reading the output to at least one significant figure (preferably two).

5.0 PRECAUTIONS

5.1 Check work order for adequate information of the sample to be analyzed such as I.D. number, nominal concentration, sample pressure, components to be analyzed and type of analysis.

5.2 Check the sample container for proper identification. Check high pressure cylinder for date of last pressure test. If longer than 5 years the cylinder should be returned to the vendor.

5.3 Be sure that the analytical system and the regulator purge lines are properly vented to a hood or other air removal system.

5.4 Excessively high flow rates or long analysis times should be avoided as this could use a large amount of span or sample gas.

6.0 VISUAL INSPECTION

6.1 Examine sample container for damage.

6.2 Check the container number against the work order for agreement.

6.3 Check the analytical system for loose lines, dirty filters or missing parts.

7.0 TEST ARTICLE PREPARATION

7.1 Attach a suitable pressure regulation device to the sample container.

7.2 Secure the container and check all fittings for leaks using liquid detector such as "Snoop".

7.3 Purge regulator and sample line through the venting system.

7.4 Turn on instrument and allow to reach temperature and electronic stability. Time will depend on instruments and previous history of use.

7.5 Select two span gases, one should indicate a value above the maximum concentration of the sample being evaluated and one below the minimal concentration of the sample. Neither span gas should exhibit values closer than ±10 percent of full scale of the sample concentration.

8.0 TEST PROCEDURE

Test Sequence	Test Description	Data Output
101	Zero instrument using the same flow, pressure and range as will be used for the span and sample gases. NOTE: Pressure should be measured closely as possible to the detector inlet.	0 ± 0.1 Reading
102	Span instrument using the highest concentration standard at 95% of scale	95.0 ± 0.2
103	Switch to zero gas. If instrument does not repeat zero, adjust and repeat 102.	0 ± 0.1
104	Repeat zero and span.	
105	Introduce second span gas and record deflection Repeat twice.	Average Deflection
106	Introduce sample gas at same flow and pressure as zero and span. Repeat twice. Reading should agree within ±0.2% of full scale.	
107	Introduce zero gas and both span gases. Previous readings should agree within 0.2% of full scale. If not repeat procedure.	None
108	Record data on form #102-01.	
109	If the sample gas deflection does not fall between the two points the gas may not be within the required tolerances. Select another set of standards, repeat #106 and 107 and document results.	

9.0 DATA INPUT

Form No. 102-01 requires the following information:

- Data
- Analyzer train no.
- Mixture components
- Analyzer vendor
- Sample flow rate and pressure
- FID pressure, air & fuel
- Operators initials
- Cylinder number analyzed
- Nominal concentration
- Analyzer setup data
  Low end concentration - meter deflection
  High end concentration - meter deflection
  Meter deflection of gas analyzed
- Comments: Reference for standard gases used and zero gases.

10.0 DATA ANALYSIS

10.1 Determine if low point and high point concentrations are adequate to determine the sample concentration. Reliability of the data is a function of the separation of the two standards and the closeness to one of the two standards.

10.2 Determine that the deflection for the sample gas is between (or close to) the deflections for the bracketing standards.

10.3 Confirm that operating parameters are within normal or recommended specifications.

10.4 Check the calculated concentrations for apparent agreement with deflection.

10.5 Note comments for possible conflicts or indication of problems.

11.0 DATA OUTPUT

11.2 Data entered into cylinder inventory file.

11.3 Data sent to person or company by division representative requesting the analysis.

12.0 ACCEPTANCE CRITERIA

12.1 Instrument technician must determine that repetition of the zero gas is within ±0.1 deflection and that the span is within ±0.2 deflections.

12.2 Deflection for the sample gas must be between the deflections for the two standards.

12.3 The sample gas concentration determined must meet the blending specifications requested from vendor.

13.0 QUALITY PROVISIONS

13.1 Repetition of span and zero readings

13.2 Repetition of sample readings

13.3 Repetition of span and zero after sample analysis

13.4 Data verification (10.0)

13.5 Acceptance criteria (12.0)

GAS BLEND ANALYSIS DATA

DATE	ANALYZER TRAIN NO	MIXTURE COMP.		ANALYZER VENDOR	SAMPLE FLOW RATE		FID PRESSURE		OPER. INIT.	
		GAS	BAL'		SCFH	"H_2O	AIR	FUEL		
– –										

5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80

CYLINDER NO. ANALYZED	NOMINAL CONCENTRATION (3)	ANALYZER SETUP DATA (NOTE)				(3) METER DEFL.	COMMENTS:
		LOW END CONC. (1)	METER DEFL.	HIGH END CONC. (2)	METER DEFL.		

5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80

NOTE: Use verified, gravimetric, or NBS cylinders for analyzer setup values.

Form 102-01

Section 200

CALIBRATION

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EPA TEST PROCEDURE	**Number** TP-201	**Page** 1 **of** 7

SUBJECT CVS CALIBRATION PROCEDURE FOR POSITIVE DISPLACEMENT PUMP	
Reference Federal Register, Vol. 38, No. 124, June 28, 1973, Appendix III, 85.075-20	**Data Form No.** 201-01
Responsible Organization Correlation and Maintenance	**Computer Program** SAQF:CALIBCVS
Test Witness Corr. and Maint. Technician/Quality Assurance	**Performance Interval** See Remarks
Type of Test Report Computer Print-Out	**Supersedes** New
Report Distribution Quality Assurance, Test Operations, Correlation & Maint.	**Superseded by**

REMARKS/COMMENTS

1.0 CVS must be calibrated every 0, 50, 100, 200, 400, 800, etc., hours of use or after major breakdown, cleaning and modification. The CVS will also be calibrated as required to meet specific contract requirements.

ORIGINAL RELEASE APPROVALS

Office	Section	Signature	Date
Program Mgmt.	Quality Assurance		
Lab. Branch	Test Oper. Chief		
Lab. Branch	Facilities Support Chief		

REVISIONS

Change Letter	Description of Change	Approval	Date

Preceding page blank

1.0 PURPOSE

To measure the various parameters which must be assessed to establish the flow rate of the constant volume sampler pump. All the parameters related to the pump are simultaneously measured with the parameters related to a flowmeter which is connected in series with the pump. The calculated flow rate (ft^3/rev. @ pump inlet absolute pressure and temperature) can then be plotted versus a function that is the value of specific combinations of pump parameters.

2.0 TEST ARTICLE DESCRIPTION

A constant volume sampler which meets requirements stated in Federal Register 85.075-20.

3.0 REFERENCES

3.1 Federal Register, Vol. 38, No. 124, June 28, 1973, 85.075-20,- Appendix III

3.2 EPA, Ann Arbor, Preventive Maintenance Guidelines - Section I

4.0 REQUIRED EQUIPMENT

The following equipment is required to perform the CVS calibration:

4.1 LFE - Laminar Flow Element (calibrated by manufacturer)

4.2 Micromanometer (see 7.3 for calibration check)

4.3 Thermometer

4.4 Timing mechanism

4.5 U-tube Manometers

4.6 Temperature Indicator with "J-Type" thermocouples (see procedure #TP205 for calibration)

4.7 A variable flow restrictor with appropriate piping to connect CVS pump and LFE.

5.0 PRECAUTIONS

5.1 Special care should be taken in the initial set-up of the calibration equipment. Leaks in the system or faulty calibration equipment will void the calibration.

5.2 The variable flow restrictor valve should be placed in the "open position" at the start of the calibration. CAUTION: never completely close the valve while the pump is in operation; the motor may be damaged.

5.3 Temperature stability during the calibration is absolutely necessary. Air handling equipment must be shut off to avoid the normal 4°F oscillations. Gradual temperature increases (2°F are acceptable as long as they occur over a period of several minutes.

5.4 Thermocouples must be checked for accuracy using a laboratory grade thermometer.

6.0 VISUAL INSPECTION

6.1 Check LFE to CVS pump connections for loose fittings

6.2 Check manometers for level placement.

6.3 Check thermocouple connections for tightness.

7.0 TEST ARTICLE PREPARATION

7.1 Connect system as shown in Figure below.

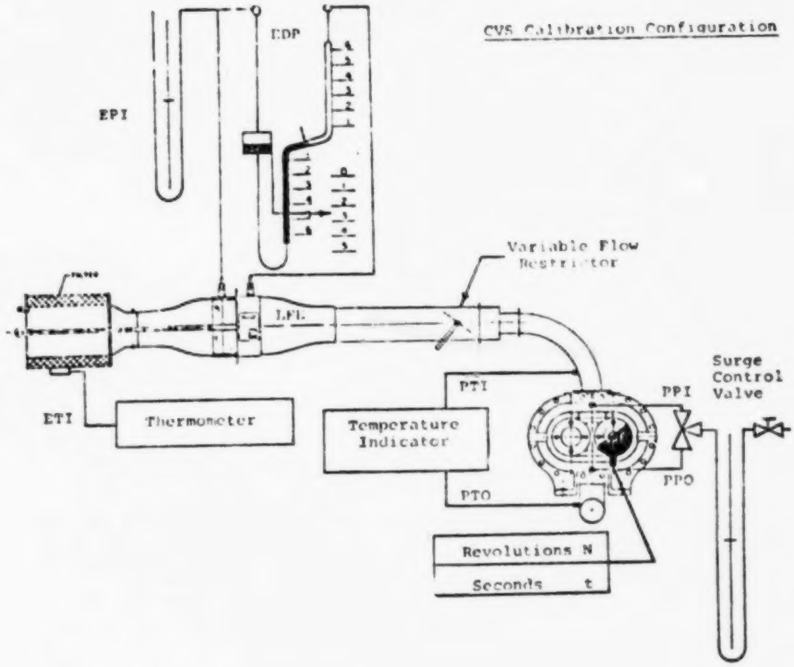
CVS Calibration Configuration
EDP
EPI
Variable Flow Restrictor
LFE
ETI
Thermometer
PTI
Temperature Indicator
PTO
PPI
PPO
Surge Control Valve
Revolutions N
Seconds t

Figure 7-1

7.2 Connect the LFE and variable flow restrictor to the CVS. Carefully seal all connections to eliminate any leakage between the LFE and CVS pump. NOTE: Refer to previous LFE inlet ΔP, a major drop may indicate a leak in connection.

7.3 Position the micromanometer and level the base using the adjustable feet provided. Set the vertical and the vernier scales on zero and check the meniscus to assure that it is between the hairline reference marks. If not, adjust the fluid at the rear of the case until the meniscus is zeroed. Connect the LFE to the micromanometer and U-tube manometer with leaktight flexible tubing. (See Figure 7-1.)

7.4 Attach the thermometer to the filter of the LFE so that the temperature of the air entering the LFE is indicated.

7.5 Check that the zero level of the U-tube manometers and adjust their scales accordingly.

7.6 Check that the CVS timer starts and stops when the counter power button is pushed.

7.7 Connect the thermocouples to the CVS at the pump inlet and outlet as shown in 7.1. The fittings normally used for sampling, temperature, or sample dump connections may be used for thermocouples.

7.8 Start the CVS pump and open the U-tube manometer surge control valve 1/4 turn. Check the fluid column surge; adjust the valve to insure the fluid will not oversurge (most surge control valves have been replaced by a 20 gauge hypodermic capillary fitting.) when switched from vacuum to pressure. NOTE: Two manometers may be used to measure these differentials simultaneously.

7.9 With the CVS pump running (20 minute warmup), adjust the micromanometer to the null position by cranking the vernier down. Operate the revolution counter and timer to insure proper operation.

7.9.1 Check the revolution counter by measuring revolutions of the pump using a strobotac and comparing the total revs. indicated on the counter for a 3-minute period.

8.0 TEST PROCEDURES

The following data will be collected and recorded in order to calculate the CVS calibration curve.

Parameter	Symbol	Units	Tolerance (accuracy of data collected)
Barmetric Pressure (Corrected)	P_B	"Hg	±.01 "Hg
Ambient Temperature	T_A	°F	±.5 °F
Air Temperature into LFE	ETI	°F	±.1 °F
Pressure depression upstream of LFE	EPI	"H_2O	±.05 "H_2O
Pressure drop across LFE meeting matrix	EDP	"H_2O	±.005 "H_2O
Air temperature at CVS pump inlet	PTI	°F	±.5 °F
Pressure depression at CVS pump inlet	PPI	"Fluid	±.05 "Fluid
Specific Gravity of Manometer fluid	Sp.Gr.	"Fluid	±.05 "Fluid
Pressure differential at CVS pump outlet	PPO	"Fluid	±.05 "Fluid
Air temperature at CVS pump outlet	PTO	°F	±.5 °F
Pump revolutions during test period	N	Revs.	±0
Elapsed time for test period	t	Secs.	±.05 Secs.

Test Sequence	Test Description	Data Output
101	Set variable restrictor valve in the wide open position and run CVS pump for 20 minutes	-0-
102	Start counter and timer	
103	Read air temperature at CVS outlet	PTO, °F
104	Read pressure depression at CVS pump inlet	PPI, "Fluid
105	Read pressure differential at CVS pump outlet	PPO, "Fluid
106	Read ambient temperature	T_A, °F
107	Read barometric pressure (corrected)	P_B, "Hg
108	Read air temperature at CVS inlet	PTI, °F
109	Read pressure depression upstream of LFE	EDP, "H_2O
110	Read air temperature in LFE	ETI, °F
110A	Read ΔP across the LFE matrix	EDP, "H_2O
111	Read pump revolutions for test period	N, Revs.
112	Record elapsed time for test period	t, secs.
113	Reset the restrictor valve to a more restricted condition. A change of about 4"H_2O is adequate to yield a minimum of six data points	
114	Allow system to stabilize for a minimum of 3 minutes	-0-
115	Repeat steps 102 through 114 until sufficient data points have been established	-0-
116	Adjust temperature controller and temperature recorder on the CVS to indicate the proper inlet temperature. Disconnect the micromanometer and recheck zero setting	
117	Disassemble the calibration setup and reconnect all pipes and fittings as used in NORMAL CVS operation. Check sample flow rates and other indicators for normal operation	

9.0 DATA INPUT

9.1 Complete data form 201-01
9.2 Submit data sheet for analysis.

10.0 DATA ANALYSIS

10.1 Analyze data using SAQF:CALIBCVS
10.1.1 These are linear fits of V_o vs. X_o and RPM vs ΔP.

11.0 DATA OUTPUT

11.1 Printed computer output
11.2 CVS coefficients for storage in Instrument Data File.

12.0 ACCEPTANCE CRITERIA

12.1 Verify new curve against previous curve and tracer gas readings previously obtained.

12.2 All V_o measured values must lie within ±0.50% of the calculated V_o values. All RPM measured speeds must be within ±0.25% of the calculated RPM values.

12.3 Check and verify that the V_o vs X_o intercept is approximately 350 ft^3/rev and the RPM vs ΔP intercept is related to the synchronous speed of the blower motor.

13.0 QUALITY PROVISIONS

13.1 An excessive shift from old curve to new curve may constitute an invalid test, therefore an investigation of cause should be implemented.

13.2 Corrective action must be implemented if malfunctions are found and the procedure must be repeated.

CVS CALIBRATION DATA SHEET

				← MANOMETER FLUID →							
				LAMINAR ELEMENT		CVS PUMP					
CVS UNIT	LAMINAR ELEMENT NO.	CALIBRATION DATE	# POINTS	SP.GR.	UNITS	SP.GR.	UNITS	EFFECTIVE TEST #	CVS VENDOR	PUMP RANGE (CFM)	CVS ELAPSED HOURS
–		– –									

5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80

	AMBIENT		LAMINAR FLOW ELEMENT			CVS PUMP					
#	BARO ("HG)	T (°F)	T_{IN} (°F)	P_{IN} *	ΔP *	T_{IN} (°F)	P_{IN} *	T_{OUT} (°F)	P_{OUT} *	REV (COUNTS)	TIME (SECS)
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											

5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80

*NOTE: Indicate manometer units and fluid specific gravity on card one.

UNITS:
IN = Inches
CM = Centimeters
MM = Millimeters

Form [illegible]1-01

```
                          CVS FLOW CALIBRATION

                               ************
                               *  CVS-09C *
                               ************

         LAMINAR ELEMENT: Y722919               CALIBRATION DATE: 07-13-74
              CVS VENDOR: AMI                    EFFECTIVE TEST #:
              PUMP RANGE: 300 CFM              CVS ELAPSED HOURS: 1080.9

         MANOMETER SPECIFICATIONS:
              LAMINAR ELEMENT: IN. OF  1.00 SPECIFIC GRAVITY FLUID
                     CVS PUMP: IN. OF  1.75 SPECIFIC GRAVITY FLUID

     MEASURED DATA:

      AMBIENT     LAMINAR ELEMENT                      CVS PUMP
     ********** ****************** ****************************************
      BARO    T     T      P     DELTA     T     P      T      P     REV    TIME
                  (IN)   (IN)      P     (IN)  (IN)  (OUT)  (OUT) COUNTS  (SECS)
     29.21 82.0 83.4   4.85   7.594   80.0 17.70    0.0 19.40   6289. 257.30
     29.21 83.0 83.4   4.75   7.510   81.0 19.30    0.0 19.00   6187. 253.30
     29.21 83.0 83.5   4.65   7.414   81.0 21.30    0.0 18.70   6516. 267.20
     29.21 83.0 83.5   4.55   7.303   81.0 23.35    0.0 18.35   6278. 257.60
     29.21 83.0 83.6   4.50   7.221   80.0 25.10    0.0 18.10   6138. 252.20
     29.21 83.0 83.8   4.45   7.118   80.0 27.40    0.0 17.75   6213. 255.70
     29.20 83.0 84.0   4.35   7.046   80.0 29.00    0.0 17.55   6125. 252.40

     CALCULATED DATA:

                CF/REV   CF/REV               SCFM   PUMP    RPM     RPM
        X       ACTUAL    CALC   CALC/ACT            DIFF    ACT     CALC  CALC/ACT
     .000265   0.2902   0.2903   1.0003    376.0    4.78 1466.5 1466.8 1.0001
     .000270   0.2901   0.2898   0.9990    372.0    4.94 1465.5 1465.4 0.9999
     .000276   0.2897   0.2891   0.9981    367.3    5.16 1463.2 1463.6 1.0003
     .000282   0.2886   0.2885   0.9997    362.0    5.38 1462.3 1461.7 0.9996
     .000288   0.2877   0.2879   1.0008    357.9    5.57 1460.3 1460.1 0.9999
     .000295   0.2872   0.2872   0.9997    352.7    5.82 1457.9 1457.9 1.0000
     .000300   0.2870   0.2866   0.9986    348.9    6.00 1456.0 1456.4 1.0003

     EQUATIONS:

                   RPM = (-.848182E 01 * DIFF) + (0.150733E 04)

                   CF/REV = (-.104931E 03 * X) + (0.318100E 00)

     CF/REV = CUBIC FEET PER REVOLUTION @ ABSOLUTE INLET TEMP AND PRESSURE
     X = (1/RPM) * SQRT(DIFF / ABSOLUTE OUTLET PRES )
     DIFF = DIFFERENTIAL PRESSURE ACROSS THE CVS PUMP IN INCHES OF MERCURY

                     PROCESSED:  14:40.27  JUL 15, 1974
```

EPA TEST PROCEDURE

Number TP-202	Page 1 of 9	

SUBJECT DYNAMOMETER CALIBRATION	
Reference Federal Register, Vol. 38, No. 124, June 28, 1973 Appendix II, 85.075-15(d)	Data Form No. 202-1
Responsible Organization Correlation and Maintenance	Computer Program DYNAHP
Test Witness/Review Corr. & Maint. Technician, Quality Assurance	Performance Interval Monthly
Type of Test Report Computer Print-Out	Supersedes New
Report Distribution Quality Assurance, Test Operations, Support Services, file	Superseded by

REMARKS/COMMENTS

NOTE: This procedure is in the revision phase by EPA, Ann Arbor. The final version will reflect new changes.

ORIGINAL RELEASE APPROVALS

Office	Section	Signature	Date
Program Mgmt	Quality Assurance		
Lab Operations	Chief		
Lab Operations	Support Services Chief		

REVISIONS

Change Letter	Description of Change	Approval	Date

1.0 PURPOSE

The purpose of the dynamometer calibration procedure is to insure that the indicated speed and the indicated absorbed power (torque) are correct and to determine the frictional loss characteristics of the dynamometer.

2.0 TEST ARTICLE DESCRIPTION

2.1 A direct drive chassis dynamometer, having the capabilities described in Federal Register 85.075-15.

2.2 Speed and torque (hp @ 50mph) meters and controls

3.0 REFERENCES

3.1 Federal Register, Vol. 38, No. 124, June 28, 1973 - Appendix II

3.2 EPA, Ann Arbor, Preventive Maintenance Guidelines, Section III.

3.3 SAE XJ1094 "Constant Volume Sampler System for Exhaust Emission Measurement," Section 3.7

4.0 REQUIRED EQUIPMENT

4.1 Test vehicle

4.2 Stroboscopic tachometer or electronic RPM counter (see manufacturer's manual for calibration procedure)

4.3 Adjustable DC power supply, upper value of at least 8 volts DC

4.4 Weight stand, Clayton

4.5 Weights, 35 pounds and 10 pounds

4.6 Tachometer generator assembly, Clayton

4.7 Varian 614A, strip chart recorder (see procedure #204 for calibration procedure)

4.8 Stopwatch or electric timer (±.1 sec.)

5.0 PRECAUTIONS

5.1 Inflate the rear tires to 45 psi to protect against blow-outs and to equalize the contact (especially important with front-wheel drive and radials)

5.2 Align vehicle on dynamometer. (Drive vehicle on to the dyno, with vehicle perpendicular to the rolls, insuring that the front wheels are centered to prevent the rear wheels from sliding off the rolls.)

5.3 Operate vehicle cooling fan within 12 inches of vehicle radiator.

5.4 Vent vehicle exhaust.

6.0 VISUAL INSPECTION

6.1 Check equipment set-up. (see sec. 7.0 and 8.0 for set-up instructions.

7.0 TEST ARTICLE PREPARATION

NOTE: Prior to calibration assure that the dynamometer is warmed up in accordance with procedure #TP-604

7.1 Speed Meter Calibration

7.1.1 Adjust mechanical zero of the speed meter with rolls stopped.

7.1.2 Place range switch to "LO" position.

7.1.3 Record dynamometer Serial Number.

7.1.4 Place vehicle on dynamometer and tie it down.

7.1.5 Engage flywheels for 4,000 pounds inertia.

7.1.6 Check index on the end of front roll for visibility.

7.1.7 Precondition the dynamometer by operating vehicle at 30 mph for 15 minutes.

7.1.8 Warm up strobotac and calibrate strobotac according to manufacturer's specifications.

7.2 Power Meter Calibration

7.2.1 All calibration steps take place with dynamometer rolls in stationary position.

7.2.2 Disconnect tachometer leads from torque bridge terminals.

7.2.3 Attach variable voltage power supply to the torque bridge terminals.

7.2.4 Adjust meter to zero with power supply off.

7.3 Determination of Actual Power Absorption

7.3.1 Inspect the dynamometer and service according to manufacturer's recommended procedure.

7.3.2 Install tachometer generator on the dynamometer frame. Line up the tach generator pulley with the shaft adaptor pulley on the front roll. Insure that the center to center pulley distance is the same as the factory installed tach generator.

7.3.3 Attach front roll tachometer generator electrical leads to Varian chart recorder.

7.3.4 Drive vehicle on dynamometer and attach vehicle restraint system.

7.3.5 Disengage roll brakes.

7.3.6 Adjust recorder zero.

8.0 TEST PROCEDURE

The dynamometer calibration is actually separated into three separate procedures. Therefore, the steps listed below are listed in three sections. Section I pertains to speed meter calibration; Section II covers power meter calibration and Section III outlines the determination of actual power absorption.

SECTION I. SPEED METER CALIBRATION

Test Sequence	Test Description	Data Output
101	Operate vehicle at front roll speed of 1,800 rpm Set strobe tach at 1,800 rpm flash rate and aim at the front roll index mark. Adjust vehicle speed to hold the mark steady at 1,800 rpm.	
102	When the front roll is steady at 1,800 check the speed meter display. ECE-50 with DD-VIF will indicate 46.3 mph if speed meter is calibrated correctly.	
103	If the meter indicates other than 46.3 mph, adjust the speed meter calibration pot in the readout instrument assembly, until speed meter indicates correct speed.	
104	Repeat steps 101 through 103. If readings will not repeat within ±0.5 mph without readjustment a malfunction must be reported. Necessary maintenance should be performed before continuing with calibration.	
105	Reduce roll speed to 900 rpm and hold steady. The speed indicated on the meter should be 23.15 (±0.5) mph. Any nonlinearity will be reported and corrected. (Perform necessary maintenance before continuing procedure.)	
106	When calibration is complete, attach calibration sticker to the back of speed meter.	

SECTION II. POWER METER CALIBRATION (TORQUE)

Test Sequence	Test Description	Data Output
201	Turn on power supply and adjust voltage to display 46.3 mph on the speed meter.	

Test Sequence	Test Description	Data Output
202	Install the weight stand (Arbor) on the Torque Arm. Tighten the attaching bolt.	
203	Level the torque arm by turning ball joints in or out of the load cell.	
204	Place (one) 35 lb. weight and (one) 10 lb. weight totaling 50 lbs. on the weight stand (Arbor wt. stand = 5 lbs.). Torque/ Power meter should show 50 ft. lbs. of torque. If meter does not show proper value, adjust the meter using the Torque Meter Calibration pot.	50 ft. lbs.
205	Repeat Step 204 substituting weights: (1) 10 lb. weight = 15 ft. lbs. torque and the weight stand itself 5 lbs = 5 ft. lbs. torque on meter. The nonadjusted torque readings should agree within ±1 ft. lb. of torque. If meter does not agree within limits without readjustment, a malfunction should be reported.	15 ft. lbs. 5 ft. lbs.
206	After completing the calibration with no malfunctions, a calibration sticker should be placed on the meter.	

SECTION III. ACTUAL POWER ABSORPTION CALIBRATION

Test Sequence	Test Description	Data Output
301	Accelerate vehicle to 60 mph and hold steady. Calibrate the chart recorder at 60 mph full scale.	
302	Check the calibration of chart at 55, 50, and 45 mph. Insure that 55 and 45 mph points are easily identified.	55 = __divis. 45 = __divis.
303	Bring the vehicle to a complete stop and re-zero the recorder.	

Test Sequence	Test Description	Data Output
304	Measure the recorder chart speed with a stopwatch or other timing mechanism. This should be repeated at least 3 times for an accurate measurement of the distance the paper travels in one (1) minute. NOTE: Alternate method of measuring elapsed time: Direct measurement of time elapsed between 55 mph and 45 mph can be accomplished by starting electronic timer at 55 mph and stopping at 45 mph. This method will eliminate interpolation of chart method.	Chart Speed (inches/mins)
305	Set dynamometer inertia at 1,500 lbs. (Insure that rolls are stationary.)	--
306	Accelerate vehicle to 50 mph and hold steady. Set the Hp (torque) to lowest obtainable value.	Hp
307	Increase speed to 60 mph and use a winch or alternate means to pull vehicle off the front drive roll. Release accelerator and allow vehicle to decel (caution: insure rear wheels are completely clear of drive roll).	
308	Measure and record the elapsed time it takes the front roll to slow from 55 mph to 45 mph.	Time secs., IHP
309	Loosen the winch and allow vehicle's rear wheels to contact the front roll. Match the front roll speed and vehicle speed as closely as possible to prevent tire damage.	--
310	Repeat Steps 307-309 so that two measurements are taken at even 500 lb. increments of inertia starting at 1,500 lbs. and ending with 5,500 lbs.	Elapsed Time IHP
311	Stop vehicle and check recorder zero.	
312	Operate vehicle at 50 mph and set Hp at 8.0 indicated Hp.	
313	Repeat Steps 307-309 so that two readings are taken at each inertia setting, at 8.0 indicated Hp.	Elapsed Time
314	Repeat Step 311.	

REVISIONS:	DYNAMOMETER CALIBRATION **TEST PROCEDURE**	**PROCEDURE NO.** TP-202 **PAGE** 8 **OF** 9

Test Sequence	Test Description	Data Output
315	At a steady 50 mph reset Hp to 14.0 indicated horsepower.	
316	Repeat Steps 307-309 in order that two readings are taken at each inertia at 14.0 indicated horsepower.	Elapsed Time
317	Remove vehicle from dyno and restore all equipment to normal operating conditions.	

REVISIONS:	DYNAMOMETER CALIBRATION TEST PROCEDURE	PROCEDURE NO. TP-202 PAGE 9 OF 9

9.0 DATA INPUT

9.1 Complete form No. 202-01. Submit the form and recorder charts to the Data Branch for analysis

9.2 Transfer information to data cards for computer input.

10.0 DATA ANALYSIS

10.1 If a chart speed of 6 inches/minute or faster, elapsed time measurements for coastdowns are made from the chart. To make this measurement, the distance between the point the trace crosses the 55 mph speed and the point the trace crosses the 45 mph speed is measured to the nearest 0.01 inch. This distance is then divided by the chart speed.

10.2 A manual curve plot of actual power versus indicated absorber power (P_{Hp} vs P_{ind}) is made for each inertia setting.

10.3 Final analysis is made by computer program DYNAHP.

11.0 DATA OUTPUT

11.1 Computer print-out of inertia weight (1,500 to 5,500 lbs.) and indicated horsepower per Federal Register requirements shown in paragraph 85.075-15(d).

12.0 ACCEPTANCE CRITERIA

12.1 New calibration curve should be within ±1/2 horsepower of previous calibration (SAE XJ 1094)

12.2 Compare graph plots of calibration results with the computer output to insure the data is accurate.

13.0 QUALITY PROVISIONS

13.1 If any malfunctions are reported for speed meter or torque meters, insure the proper corrective maintenance is performed and a repeat calibration has been accomplished.

13.2 If calibration does not agree with 12.1 above, reject calibration.

13.3 Perform necessary corrective maintenance or action and repeat the calibration.

DYNAMOMETER CALIBRATION

DYNO NO.	DATE MO	DATE DY	DATE YR	DYNAMOMETER INFO:

CARD NO.	IND HP	INERTIA WT.	TIME; SEC.
2	40	1750	
3	40	2000	
4	40	2500	
5	40	3000	
6	40	3500	
7	40	4000	
8	40	4500	
9	40	5000	
10	40	5500	
11	80	1750	
12	80	2000	
13	80	2500	
14	80	3000	
15	80	3500	
16	80	4000	
17	80	4500	
18	80	5000	
19	80	5500	

CARD NO.	IND HP	INERTIA WT.	TIME; SEC.
20	140	1750	
21	140	2000	
22	140	2500	
23	140	3000	
24	140	3500	
25	140	4000	
26	140	4500	
27	140	5000	
28	140	5500	

PROGRAM: DYNAHP

FORM 202-01

```
03 02-04-74   18.8 HP 1800 RPM = 46.3 MPH

PROCESSED:  17:05.43  FEB  4, 1974  -

          ACT.     IND.     WITH
WT.       HP       HP       A/C
1750.     7.7      4.9       5.5
2000.     8.3      4.9       5.6
2250.     8.8      5.2       6.0
2500.     9.4      5.7       6.5
2750.     9.9      6.2       7.1
3000.    10.3      6.5       7.4
3500.    11.2      7.0       7.9
4000.    12.0      8.0       9.1
4500.    12.7      8.2       9.3
5000.    13.4      8.9      10.1
5500.    13.9      8.9      10.1
5500.    14.4      9.3      10.5

NOTE:  LAST 5500 VALUE IS FOR WTS ABOVE 5751#
```

```
  INPUT VALUES FOR
03 02-04-74   18.8 HP 1800 RPM = 46.3 MPH

                                       ACT. HP           CALC. HP
   WT           T         IND. HP      6.6                4.0
 1750.       16.00        4.0          7.1                3.9
 2000.       17.00        4.0          7.3                3.9
 2500.       20.80        4.0          7.3                3.9
 3000.       25.00        4.0          7.7                4.0
 3500.       27.70        4.0          7.4                3.9
 4000.       32.70        4.0          7.8                3.9
 4500.       35.10        4.0          8.0                4.0
 5000.       38.10        4.0          8.2                3.9
 5500.       40.60        4.0         11.4                8.0
 1750.        9.30        8.0         12.3                8.2
 2000.        9.90        8.0         12.2                8.2
 2500.       12.40        8.0         12.1                8.1
 3000.       15.00        8.0         12.5                8.1
 3500.       17.00        8.0         12.1                8.1
 4000.       20.00        8.0         12.6                8.1
 4500.       21.70        8.0         12.4                8.0
 5000.       24.40        8.0         13.0                8.1
 5500.       25.60        8.0         18.6               14.0
 1750.        5.70       14.0         19.0               13.9
 2000.        6.40       14.0         19.0               13.9
 2500.        8.00       14.0         18.8               13.9
 3000.        9.70       14.0         19.5               14.0
 3500.       10.90       14.0         18.7               13.9
 4000.       13.00       14.0         19.2               13.9
 4500.       14.20       14.0         19.0               14.0
 5000.       16.00       14.0         19.8               14.0
 5500.       16.90       14.0
```

EPA TEST PROCEDURE

Number TP-203

Page 1 of 6

SUBJECT
GAS ANALYZER CALIBRATION CURVE GENERATION

Reference FEDERAL REGISTER, VOL. 38 NO. 209, Oct. 31, 1973 - 85.075-23

Data Form No. 203-01

Responsible Organization
CORRELATION/MAINTENANCE

Computer Program
SAQF: CURVEALL

Test Witness/Review
QUALITY ASSURANCE

Performance Interval
See Comments

Type of Test Report
COMPUTER PRINT-OUT (DEFLECTION VS CONCENTRATION)

Supersedes
New

Report Distribution QUALITY ASSURANCE, TEST OPERATIONS, CORRELATION AND MAINTENANCE

Superseded by

REMARKS/COMMENTS

1.0 Calibration should be performed every 30 days, after any maintenance requiring re-alignment or when called for specifically by contract requirement.

ORIGINAL RELEASE APPROVALS

Office	Section	Signature	Date
Program Mgmt	Quality Assurance		
Lab Branch	Chief		
Lab Branch	Support Services Chief		

REVISIONS

Change Letter	Description of Change	Approval	Date

REVISIONS:	ANALYZER CALIBRATION	PROCEDURE NO. TP-203
	TEST PROCEDURE	PAGE 2 OF 6

1.0 PURPOSE

Measurement of exhaust components requires that the deflections obtained during the analysis be converted to concentrations as accurately as possible. This document describes the procedure to be used to construct calibration curves for the instruments which measure hydrocarbons, oxides of nitrogen, carbon dioxide and carbon monoxide.

2.0 TEST ARTICLE DESCRIPTION

The instruments being calibrated are mounted in a console with provisions for: analysis of the exhaust sample; recording the instrument outputs; and suitable gas supplies for spanning and zeroing the instruments.

3.0 REFERENCES

3.1 Federal Register, Vol. 38, No. 209, Oct. 31, 1973 - 85.075-23

3.2 SAE XJ1094, "Constant Volume Sampler System for Exhaust Emission Measurement," Section 4. (Proposed)

3.3 Operators Manuals for In Use Analyzers

4.0 REQUIRED EQUIPMENT

4.1 Exhaust gas analysis console, equipped with the following instruments:

4.1.1 Hydrocarbons by flame ionization
Beckman Model 400 or equivalent

4.1.2 Carbon monoixde by non-dispersive infrared (NDIR)
Bendix Model 8501B or equivalent

4.1.3 Carbon dioxide by non-dispersive infrared (NDIR)
MSA Model 202 or Beckman Model 315B or equivalent

4.1.4 Oxides of nitrogen by chemiluminescence
Teco Model 10A or equivalent

4.1.5 Flow controls for selecting and monitoring the gases

4.2 Zero gas meeting the requirements specified in FR 85.075-23 (a)(2).

4.3 Calibration (standard) gas mixtures traceable to NBS and/or EPA primary standards.

4.4 Chart recorders capable of 0-100 deflections with accuracy of ±1 percent, and a readability of ±1 percent.

4.5 Read-out device in percent of scale.

- Computer interface
- DVM
- Meter

5.0 PRECAUTIONS

5.1 Safety - Reference safety manual "Safe Handling of Compressed Gases."

5.2 Meter chart reading, D.V.M. or other output devices should have a valid calibration tag.

5.3 Check that the proper set of standards are used for the particular range being calibrated as specified by Quality Assurance.

6.0 VISUAL INSPECTION

6.1 Verify that the instrument serial number is correct for the sample train.

6.2 Check instrument gain settings against those in the instrument log book.

6.3 Check instrument response time and noise level.

7.0 TEST ARTICLE PREPARATION

7.1 Check calibration gas mixture for proper cylinder and regulation pressures.

7.2 Special checks; Converter efficiency test procedure No. 303.

7.3 Adjust analyzers to optimum performance.

7.3.1 Reference analyzer operation manuals

8.0 TEST PROCEDURE

The calibration curve is constructed from the data collected as a result of performing the following sequence of steps:

Test Sequence	Test Description	Data Output
101	Zero the instrument using zero gas flowing at the same rate used for span and sample. The HC instrument must be zeroed with air, others with nitrogen or air.	ZERO DEFL.
102	Select desired range, introduce calibration gas with highest concentration for that range. Adjust output to reading obtained in previously monthly calibration or determine theoretical percent of scale (TPS) by $\frac{\text{Cylinder Conc.} \quad \text{X100}}{\text{Range Conc.}} = \text{TPS}$ TPS should never be greater than 99 percent.	RANGE
103	Introduce zero gas. If not zero, adjust.	ZERO DEFL.
104	Introduce highest span gas	CONCENTRATION/ DEFLECTION
105	Repeat 103	
106	When steps 103 and 104 can be repeated without adjustment, go on to 107. If not within a reasonable period of time, follow instrument diagnostic and maintenance procedures. Ref. 3.3.	
107	Introduce each successively lower span gas until zero is repeated.	CONC & DEFL.
108	Introduce each successively higher span gas until highest reading is obtained.	CONC & DEFL.
109	Repeat steps 107 and 108 until all readings agree within ±0.25%. If not possible, perform instrument diagnostic and maintenance procedures. Ref. 3.3.	
110	Record average of all readings except zero on data form # 203-01	DEFLECTIONS

Test Sequence	Test Description	Data Output
111	Record the following information on the data sheet date, analyzer, train no., gas analyzer, range no., full scale concentration, analyzer vendor, NDIR cell length, units, flow rate set point, FID pressures, gain setting, recorder type used, operators initials, also cylinder numbers, and concentrations.	SEE DATA SHEET

9.0 DATA INPUT

9.1 Complete form # 203-01.

9.2 Submit the form to the Data Branch for processing.

10.0 DATA ANALYSIS

10.1 Process data using "SAQF: CURVEALL"

11.0 DATA OUTPUT

11.1 Computer print of "Curveall Super Version" Recorder Deflection vs. Concentration.

12.0 ACCEPTANCE CRITERIA

12.1 Check for linearity of NOx and HC curves.

12.2 Insure that all calibration points fit within ±2% of the point value.

12.3 Insure that no major curve shift was indicated from last calibration.

13.0 QUALITY PROVISIONS

13.1 If data does not follow "Acceptance Criteria", reject calibration and institute corrective action.

13.2 If data is acceptable and curve update is desired, check the appropriate space on the Curveall Verification sheet and return it to the Data Branch.

13.3 If data was unacceptable, upon completion of required corrective action, institute recalibration.

ANALYZER CALIBRATION
CURVE GENERATION DATA

DATE	ANALYZER TRAIN NO.	GAS ANALYZED	RANGE NO.	FULL SCALE CONC.	ANALYZER VENDOR	NDIR CELL LENGTH	UNITS	FLOW RATE SCFH	SET POINT "H2O	FID PRESSURES AIR	FID PRESSURES FUEL	FID PRESSURES SAMP	GAIN SETTINGS ZERO	GAIN SETTINGS SPAN	RECORDER TYPE USED	OPERATOR INITIALS
- -				.		.		.	.	.	.	.	.	.		

5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80

COMMENTS:

1 CYLINDER NUMBER	13 CYLINDER CONC.	21 METER DEFL.
04	.	.
	.	.
	.	.
	.	.
	.	.
	.	.
	.	.
	.	.
	.	.
	.	.

SYMBOLS AND ABBREVIATIONS

GASES - C_3H_8, CO, CO_2, NO_x, CH_4

CELL LENGTH UNITS - IN, CM

RECORDER TYPE - TI (Texas Instr.), HW (Honeywell), LN (Leeds & Northrup), DVM (Digital Voltmeter), MIS (Other).

RANGE NO. DESIGNATIONS

HC, CO, NO_x (PPM)

01 - 0 - 10
02 - 0 - 25
03 - 0 - 50
04 - 0 - 100
05 - 0 - 250
06 - 0 - 500
07 - 0 - 1000
08 - 0 - 2500
09 - 0 - 5000

CO, CO_2 (%)

01 - 0 - 1.0%
02 - 0 - 2.5%
03 - 0 - 5.0%
04 - 0 - 10.0%
05 - 0 - 15.0%

HEXANE NDIR

01 - 0 - 1000 PPM HEX
02 - 0 - 10000 PPM HEX

PROGRAM: SAQF:CURVEALL.
10-30-73

FORM 203-01

```
                                           ****************************
                                           *** CURVEALL SUPER VERSION ***
                                           ****************************
                                                                                RECORDER DEFLECTION : CONCENTRATION CO
CALIBRATION DATE : 05-20-75                                      ---------------------------------------------------------------------------
ANALYZER TRAIN   :    16                                         |               |                   |                    |                    |
GAS ANALYZED     :  CO              11        6666666666         |  0.0     0.0  | 25.0      894.79  | 50.0     2059.69  | 75.0     3512.82  |
RANGE NUMBER     :    09           111       666666666666        |  0.5    14.78 | 25.5      915.68  | 50.5     2085.46  | 75.5     3546.59  |
FULL SCALE CONC. :5000.0          1111       66        66        |  1.0    29.69 | 26.0      936.67  | 51.0     2111.34  | 76.0     3580.62  |
ANALYZER VENDOR  :  BECKMAN         11       66                  |  1.5    44.73 | 26.5      957.76  | 51.5     2137.32  | 76.5     3614.92  |
NDIR CELL LENGTH :   0.0            11       66                  |  2.0    59.91 | 27.0      978.96  | 52.0     2163.41  | 77.0     3649.49  |
SAMPLE FLOWRATE  :   0.0 SCFH       11       66666666666         |  2.5    75.23 | 27.5     1000.26  | 52.5     2189.60  | 77.5     3684.35  |
MONITOR SET POINT:  13.0 "H20       11       666666666666        |  3.0    90.67 | 28.0     1021.67  | 53.0     2215.90  | 78.0     3719.49  |
FID AIR  PRESSURE:   0.0  PSI       11       66        66        |  3.5   106.25 | 28.5     1043.18  | 53.5     2242.32  | 78.5     3754.93  |
FID FUEL PRESSURE:   0.0  PSI       11       66        66        |  4.0   121.97 | 29.0     1064.78  | 54.0     2268.84  | 79.0     3790.68  |
FID SAMP PRESSURE:   0.0  PSI       11       66        66        |  4.5   137.81 | 29.5     1086.50  | 54.5     2295.47  | 79.5     3826.73  |
ZERO GAIN        :   0.0        1111111111   666666666666        |               |                   |                    |                    |
SPAN GAIN        :   0.0        1111111111    6666666666         |  5.0   153.79 | 30.0     1108.31  | 55.0     2322.22  | 80.0     3863.10  |
RECORDER TYPE    :   DVM                                         |  5.5   169.90 | 30.5     1130.22  | 55.5     2349.09  | 80.5     3899.80  |
OPERATOR'S INIT. :    RR                                         |  6.0   186.14 | 31.0     1152.23  | 56.0     2376.07  | 81.0     3936.84  |
COMMENTS         : 0-5000 PPM CO                                 |  6.5   202.51 | 31.5     1174.34  | 56.5     2403.17  | 81.5     3974.22  |
                                                                 |  7.0   219.01 | 32.0     1196.54  | 57.0     2430.39  | 82.0     4011.96  |
                                                                 |  7.5   235.64 | 32.5     1218.85  | 57.5     2457.74  | 82.5     4050.05  |
                                                                 |  8.0   252.40 | 33.0     1241.25  | 58.0     2485.21  | 83.0     4088.52  |
                                                                 |  8.5   269.29 | 33.5     1263.75  | 58.5     2512.80  | 83.5     4127.37  |
                                                                 |  9.0   286.31 | 34.0     1286.35  | 59.0     2540.52  | 84.0     4166.61  |
   EQUATION:                                                     |  9.5   303.45 | 34.5     1309.04  | 59.5     2568.38  | 84.5     4206.25  |
   ********                                                      |               |                   |                    |                    |
                                 2         3                     | 10.0   320.73 | 35.0     1331.83  | 60.0     2596.36  | 85.0     4246.30  |
      CO = X / ( A + B*X + C*X  + D*X  )                         | 10.5   338.12 | 35.5     1354.72  | 60.5     2624.49  | 85.5     4286.78  |
                                                                 | 11.0   355.65 | 36.0     1377.70  | 61.0     2652.75  | 86.0     4327.69  |
                                                                 | 11.5   373.30 | 36.5     1400.77  | 61.5     2681.15  | 86.5     4369.05  |
   COEFFICIENTS:                                                 | 12.0   391.07 | 37.0     1423.94  | 62.0     2709.69  | 87.0     4410.87  |
   ************                                                  | 12.5   408.97 | 37.5     1447.21  | 62.5     2738.37  | 87.5     4453.15  |
                                                                 | 13.0   426.99 | 38.0     1470.57  | 63.0     2767.21  | 88.0     4495.93  |
        (A)    3.3993E-02                                        | 13.5   445.14 | 38.5     1494.02  | 63.5     2796.20  | 88.5     4539.19  |
        (B)   -3.1195E-04                                        | 14.0   463.41 | 39.0     1517.57  | 64.0     2825.34  | 89.0     4582.97  |
        (C)    3.2324E-06                                        | 14.5   481.80 | 39.5     1541.21  | 64.5     2854.64  | 89.5     4627.28  |
        (D)   -1.7609E-08                                        |               |                   |                    |                    |
                                                                 | 15.0   500.30 | 40.0     1564.95  | 65.0     2884.09  | 90.0     4672.12  |
                                                                 | 15.5   518.93 | 40.5     1588.78  | 65.5     2913.71  | 90.5     4717.52  |
  CYLINDER     RECORDER    CO   CONCENTRATIONS   % POINT         | 16.0   537.68 | 41.0     1612.70  | 66.0     2943.50  | 91.0     4763.49  |
   NUMBER     DEFLECTION  CYLINDER  CALCULATED  DEVIATION        | 16.5   556.55 | 41.5     1636.72  | 66.5     2973.46  | 91.5     4810.04  |
 ***********  **********  ********  **********  *********        | 17.0   575.54 | 42.0     1660.83  | 67.0     3003.59  | 92.0     4857.20  |
                 (X)                   (Y)                       | 17.5   594.64 | 42.5     1685.04  | 67.5     3033.91  | 92.5     4904.98  |
 A2827          26.90     976.172    974.712      -0.15          | 18.0   613.86 | 43.0     1709.34  | 68.0     3064.40  | 93.0     4953.40  |
 AA1594         40.40    1576.569   1584.002       0.47          | 18.5   633.20 | 43.5     1733.73  | 68.5     3095.07  | 93.5     5002.47  |
 A8442          56.10    2396.885   2381.482      -0.64          | 19.0   652.65 | 44.0     1758.22  | 69.0     3125.94  | 94.0     5052.23  |
 A3397          71.80    3283.272   3302.510       0.59          | 19.5   672.21 | 44.5     1782.81  | 69.5     3157.00  | 94.5     5102.67  |
 A6146          83.90    4170.984   4158.727      -0.29          |               |                   |                    |                    |
 A9172          95.30    5182.027   5184.883       0.06          | 20.0   691.89 | 45.0     1807.49  | 70.0     3188.26  | 95.0     5153.83  |
                                                                 | 20.5   711.69 | 45.5     1832.27  | 70.5     3219.73  | 95.5     5205.73  |
       AVERAGE PERCENT OF POINT DEVIATION:  0.37                 | 21.0   731.59 | 46.0     1857.15  | 71.0     3251.40  | 96.0     5258.39  |
                                                                 | 21.5   751.61 | 46.5     1882.12  | 71.5     3283.28  | 96.5     5311.84  |
                                                                 | 22.0   771.73 | 47.0     1907.19  | 72.0     3315.38  | 97.0     5366.09  |
                                                                 | 22.5   791.97 | 47.5     1932.35  | 72.5     3347.70  | 97.5     5421.17  |
                                                                 | 23.0   812.32 | 48.0     1957.62  | 73.0     3380.24  | 98.0     5477.10  |
                  ***PROCESSED:  15:43  MAY 20, 1975             | 23.5   832.78 | 48.5     1982.99  | 73.5     3413.02  | 98.5     5533.92  |
                                                                 | 24.0   853.34 | 49.0     2008.45  | 74.0     3446.04  | 99.0     5591.65  |
                         ***LOGGED ON LINE:  389                 | 24.5   874.01 | 49.5     2034.02  | 74.5     3479.31  | 99.5     5650.32  |
                         ***TO: 162/209 05-20-75                 |               |-------------------|--------------------|--------------------|
```

EPA TEST PROCEDURE	Number TP-204	Page 1 of 3

SUBJECT CHART RECORDER/MAINTENANCE	
Reference MANUFACTURER'S SERVICE MANUALS	Data Form No. INSTR. LOGBOOK
Responsible Organization INSTRUMENT SERVICES	Computer Program NONE
Test Witness /Review INSTRUMENT SERVICES LEADER/QUALITY ASSURANCE	Performance Interval MINIMUM: 90 DAYS
Type of Test Report CALIBRATION STICKER AND LOG BOOK ENTRY	Supersedes New
Report Distribution QUALITY ASSURANCE, INSTRUMENT SERVICES	Superseded by

REMARKS/COMMENTS

ORIGINAL RELEASE APPROVALS

Office	Section	Signature	Date
Program Mgmt	Quality Assurance		
Lab Branch	Chief		
Lab Branch	Support Services Chief		

REVISIONS

Change Letter	Description of Change	Approval	Date

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1.0 PURPOSE

To perform periodic recalibration and maintenance after periods of use or questionable performance. Recalibration will assure accurate instrument output and prolong the useful life of the instrument.

2.0 TEST ARTICLE DESCRIPTION

2.1 Chart recorder, two channel model capable of measuring two variables on the same chart. The recorder is a continuous balance potentiometer which responds to a d-c signal representing the value of the measured quantity.

2.2 Typical chart recorders used may be:

- o Honeywell 194 Electronik
- o Varian G-14A-2
- o Varian G-1110
- o Hewlett-Packard 680
- o Texas Instruments 4525-2, 7822-2 (4 pen)
- o Texas Instruments 2596-2 (2 pen)

3.0 REFERENCES

Each recorder listed in 2.2 has a manual showing theory/operation, maintenance and calibration procedures. These manuals are available and should be reviewed by the instrument technicians.

4.0 REQUIRED EQUIPMENT

The list of equipment in this section represents an example of the articles needed to perform a valid calibration. It should be noted that manufacturers of specific equipment may list requirements for their own calibration items.

4.1 Example of calibration equipment

- o Calibrated precision voltage source.
  Example: Honeywell Model 2746 portable potentiometer, 0-200 microvolt to 0-500 millivolt ranges.

- o Test leads (preferably with banana plugs)
- o Calibration screwdrivers (1/8" and 1/4" bits)

5.0 PRECAUTIONS

5.1 Calibration and adjustment of recorders should be accomplished by Instrument Service Technicians only.

5.2 Safety precautions should be observed in using electrical equipment.

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6.0 VISUAL INSPECTION

6.1 Inspect slidewires for signs of wear.

6.2 Inspect RECORDER for disconnected leads and/or broken wires.

7.0 TEST ARTICLE PREPARATION

7.1 Set up calibration equipment as specified in applicable service manual.

8.0 TEST PROCEDURE

Each manufacturer of chart recorders outlines specific calibration procedures common to their product. Therefore, the test procedures for chart recorder calibration should be taken from the manufacturer's text. It is also suggested that routine maintenance should be accomplished prior to the calibration of each recorder.

9.0 DATA INPUT

9.1 The date of calibration, type of instrument, serial number, and work performed is recorded in instrument calibration log book (see attachment).

10.0 DATA ANALYSIS

10.1 Observed readings and calibration input should be compared.

11.0 DATA OUTPUT

11.1 Calibration sticker showing the date of calibration and the date the next calibration is due is attached to the recorder. Calibration data sheet shall be filed in the instrument file and logged in the record book.

12.0 ACCEPTANCE CRITERIA

12.1 Recorder must function within ±1 percent accuracy and repeatability following calibration.

13.0 QUALITY PROVISIONS

13.1 Check to assure calibration has been completed at proper time intervals.

13.2 Assure that calibration sticker has been placed on recorder.

TP-204 ATTACHMENT No. 1
INSTRUMENT SERVICES LOG BOOK

MAKE	MODEL	SERIAL NO.	DATE CALIBRATED	DATE DUE	TECH.	REMARKS
ESTERLINE	E1124E	940456	8-29-74	11-29-74	D.P.	REPLACED INK PAD & PRINT WHEE.
"	"	940757	10-11-74	1-11-75	D.P.	1° LOW PRIOR TO CAL.
HONEYWELL	194E	5103576E	12-7-74	3-7-75	J [illegible]	GAIN HIGH PRIOR TO CAL
TEX INSTR.	2596-2	T135701	12-9-74	3-9-75	[illegible]	REPLACED SLIDE WIRE

EPA TEST PROCEDURE	Number TP-205	Page 1 of 4

SUBJECT
TEMPERATURE RECORDER CALIBRATION/MAINTENANCE

Reference MANUFACTURER'S SERVICE MANUAL	Data Form No. LOG BOOK
Responsible Organization INSTRUMENT SERVICES	Computer Program NONE
Test Witness/Review INSTRUMENT SERVICES LEADER, QUALITY ASSURANCE	Performance Interval MINIMUM: 90 DAYS
Type of Test Report LOG BOOK ENTRY AND CALIBRATION STICKER	Supersedes NEW
Report Distribution QUALITY ASSURANCE, INSTRUMENT SERVICES	Superseded by

REMARKS/COMMENTS

ORIGINAL RELEASE APPROVALS

Office	Section	Signature	Date
Program Mgmt	Quality Assurance		
Lab Branch	Chief		
Lab Branch	Support Services Chief		

REVISIONS

Change Letter	Description of Change	Approval	Date

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REVISIONS:	TEMPERATURE RECORDER CALIBRATION/MAINTENANCE **TEST PROCEDURE**	PROCEDURE NO. TP-205 PAGE 2 OF 4

1.0 PURPOSE

To perform periodic re-calibration and maintenance after periods of use and/or questionable performance. Re-calibration of temperature recorders will assure accurate instrument output and prolong the instrument's useful life.

2.0 TEST ARTICLE DESCRIPTION

Temperature recorders vary in make, however, the operating principles are generally the same. A temperature probe (normally iron-constantan thermocouple) senses the temperature and produces an unknown voltage which is in turn subtracted from a known voltage. The difference in voltages is amplified and displayed by the recorder

2.1 Temperature recorders vary in application, ranging from one channel to as many as 24 channels for measuring independent variables.

The following recorders are representative of the types used in emission monitoring.

- Esterline Corp., 24-channel, Model E1124E
- Honeywell, 24-channel, Model Elect. 19
- Honeywell, multi-channel, Model Elect 15
- Rustrax, single-channel, Model 2133

3.0 REFERENCES

Each recorder listed in 2.1 has a manual showing theory/operation, maintenance and calibration procedures. Manuals of this nature must be made available to the instrument technicians.

4.0 REQUIRED EQUIPMENT

The list of equipment in this section represents an example of the articles needed to perform a valid calibration. It should be noted that manufacturers of specific equipment may list requirements for their own calibration items.

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4.1 Example of calibration equipment

- o Precision voltage source (used for input voltages from temperature-EMF equivalents) reference 0° C or 32° F.
- o Thermocouple extension wire
- o Ice bath for 0° C or 32° F reference.
- o Reference standard, Hewlett-Packard temperature indicator - Quartz digital

5.0 PRECAUTIONS

5.1 Dangerous stray voltages exist. Before touching connections, turn off power and check each terminal with a multimeter.

5.2 Calibration and adjustment of recorders should be accomplished by Instrument Service technicians only.

6.0 VISUAL INSPECTION

6.1 Inspect for obvious signs of wear.

6.2 Inspect for disconnected leads and/or broken wires.

7.0 TEST ARTICLE PREPARATION

7.1 Set up calibration equipment as specified in applicable service manual.

8.0 TEST PROCEDURE

Each manufacturer of temperature recorders outlines specific calibration procedures common to their product. Therefore, the test procedures for the recorder calibration should be taken from the manufacturer's text. It is also suggested that routine maintenance should be accomplished prior to the calibration of each recorder.

9.0 DATA INPUT

9.1 The date of calibration, type of instrument, serial number, and work performed is recorded in instrument calibration log book (see attachment).

REVISIONS:	TEMPERATURE RECORDER CALIBRATION/MAINTENANCE **TEST PROCEDURE**	PROCEDURE NO. TP-205 PAGE 4 OF 4

10.0 DATA ANALYSIS

10.1 Compare observed temperature readings with the reference standard.

11.0 DATA OUTPUT

11.1 Calibration sticker showing the date of calibration and the date the next due calibration is attached to the recorder.

11.2 Information regarding the results of the calibration shall be filed with the instrument records.

12.0 ACCEPTANCE CRITERIA

12.1 Temperature recorder must indicate ambient temperature within ±2 degrees of the true value.

12.2 Temperature indicated must be within 1 percent of full scale at all points.

13.0 QUALITY PROVISIONS

13.1 If acceptance criteria are not met, repair instrument and/or repeat calibration.

TP-205 ATTACHMENT No. 1

INSTRUMENT SERVICES LOG BOOK

MAKE	MODEL	SERIAL NO.	DATE CALIBRATED	DATE DUE	TECH.	REMARKS
ESTERLINE	E1124E	940456	8-29-74	11-29-74	L.P	REPLACED INK PAD & PRINT WHEEL
"	"	940757	10-11-74	1-11-75	L.P.	1° LOW PRIOR TO CAL.
HONEYWELL	194E	3103576E	12-7-74	3-7-75	J.	GAIN HIGH PRIOR TO CAL
TEX. INSTR.	2596-2	7135701	12-9-74	3-9-75	\	REPLACED SLIDE WIRE

EPA TEST PROCEDURE

Number TP-206

Page 1 of 9

SUBJECT
BAROMETRIC PRESSURE
CALIBRATION AND CORRELATION

Reference Federal Register, Vol. 39, No. 101, May 23, 1974, 85.075-22(j)	Data Form No. Log Book
Responsible Organization Chemical Analysis	Computer Program None
Test Witness/Review Correlation and Maintenance	Performance Interval Monthly
Type of Test Report Log Book Entry	Supersedes New
Report Distribution Chemistry Section, Support Services	Superseded by

REMARKS/COMMENTS

ORIGINAL RELEASE APPROVALS

Office	Section	Signature	Date
Program Mgmt.	Quality Assurance		
Lab. Branch	Chief		
Lab. Branch	Support Services Chief		

REVISIONS

Change Letter	Description of Change	Approval	Date

1.0 PURPOSE

To calibrate the aneroid barometers use in the test call against a Fortin type barometer to assure accurate and uniform test cell readings.

2.0 TEST ARTICLE DESCRIPTION

Aneroid barometer compensated for temperature, brass, scale 25.1-31.1 inches of mercury (Hg), 0.02 subdivisions.

3.0 REFERENCES

3.1 PRINCO Barometer Instruction Booklet

3.2 W.G. Brombacher, D.P. Johnson, and J.L. Cross.,
"Mercury Barometers and Manometers"
NBS Monograph 8, May 1960.

4.0 REQUIRED EQUIPMENT AND CONDITIONS

4.1 Fortin type barometer, 1/4 inch bore, reading by vernier to 0.01 in. Hg

4.2 Rack for hanging the aneroid barometers

4.3 Temperature controlled room of ±3°F.

5.0 PRECAUTIONS

5.1 The Fortin type barometer readings are corrected for temperature and gravity. The aneroid barometer is set to the corrected barometer reading.

5.2 The aneroid barometers may indicate a slightly different reading from one cell to another due to variations in the air handling system. Large variations indicate a need for calibration or replacement.

5.3 Important factors which could affect the reading of the height of the mercury are

- Lighting - Proper illumination is essential to define the location of the crown of the meniscus. Precision meniscus sighting under optimum viewing conditions can approach ± 0.001 in. Contact between index and mercury surface in the cistern, judged to be made when a small dimple in the mercury first disappears during adjustment, can be detected with proper lighting to much better than ± 0.001 in.
- Temperature - To keep the uncertainty in height within 0.01% (0.003 in. Hg), the mercury temperature must known within

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±1°F. Although it is generally assumed that the scale and mercury temperatures are identical, the scale temperature need not be known to better than ±10°F for comparable accuracy. Uncertainties caused by nonequilibrium conditions could be avoided by installing the barometer in a uniform temperature room.

- Alignment - Vertical alignment of the barometer tube is required for an accurate pressure determination. The Fortin barometer, designed to hang from a hook, does not of itself hang vertically. This must be accomplished by a separately supported ring encircling the cistern; adjustment screws control the horizontal position.

- Readings - The most reliable readings are obtained when the temperature has not changed greatly over the past four hours. When reading the barometer the reader's eye should be in the same horizontal plane as the top of the mercury meniscus and the lower edge of the vernier plate. This position can be checked by getting the eye in line with the bottom of the vernier plate and the bottom of the metal guide in back of the mercury column directly in back of the vernier plate.

  Readjustment to zero should be made whenever necessary in reading the barometer; i.e., the adjusting screw at the bottom of the reservoir casing should be manipulated until the surface of the mercury exactly coincides with the tip of the ivory zero point which is visible inside the reservoir.

  The height of the meniscus will be greater on a rising barometer than on a falling barometer. In order to bring the meniscus to its approximate average height, tap the barometer lightly with your fingers before taking a reading.

5.4 If it is desired to convert an english reading to a metric reading, or vice versa, always apply the temperature and gravity corrections before making conversion.

6.0 VISUAL INSPECTION

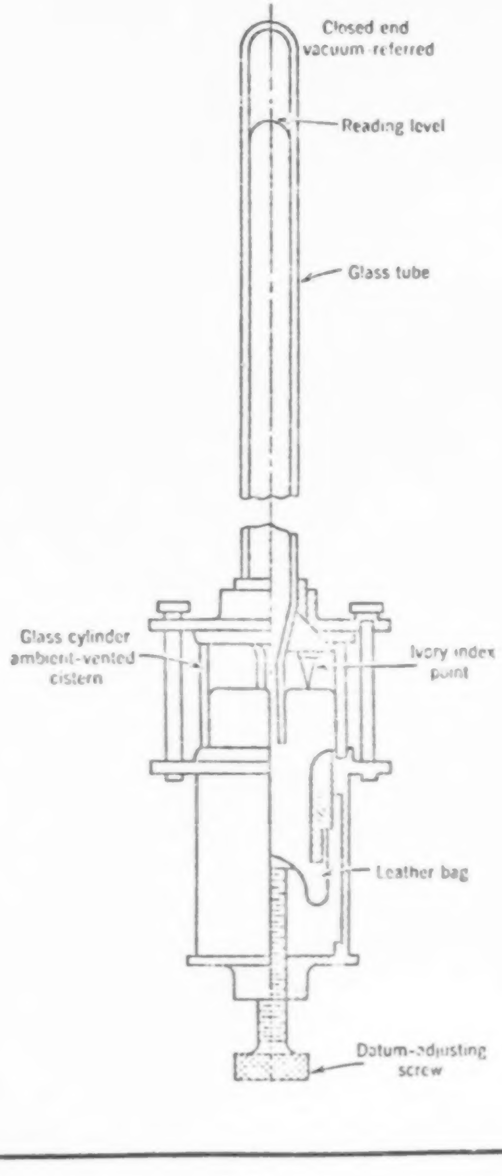
6.1 If an aneroid barometer has a cracked glass or dented case the complete barometer should be replaced. Do not attempt to recalibrate as the internal movements may have been also damaged.

6.2 If the mercury appears dull or tarnished, it is an indication that the mercury has become contaminated in some way. It frequently occurs when air, dirt, and moisture are admitted into the barometer tube. In such event the instrument will no longer give accurate readings. For proper cleaning the instrument should be returned to the factory.

7.0 TEST ARTICLE PREPARATION

7.1 The aneroid barometers to be calibrated should be hung in the ±3°F temperature controlled room for a minimum of 4 hours to allow them to come to equilibrium with the ambient conditions.

A Fortin-type barometer.


Closed end
vacuum-referred
Reading level
Glass tube
Glass cylinder
ambient-vented
cistern
Ivory index
point
Leather bag
Datum-adjusting
screw

8.0 TEST PROCEDURE

The test requires three basic procedures: A. Reading the mercury barometer, B. Calibration of the aneroid barometer and C. Correlation of the test cell barometers.

Test Sequences	Test Description	Data Output
101A	In reading a barometer of the Fortin type, which is the usual laboratory precision type, first obtain the temperature of the case from the small thermometer attached midway between the top and bottom of the instrument. Then adjust the mercury in the reservoir to the fixed point (an ivory pin), so that the tip of the pin and its image upon the mercury surface coincide. Tap the barometer case gently to be sure that the mercury is not stuck in the tube and verify the zero setting. Now bring the vernier down until the white background is cut off at the highest point of the meniscus. The reading is the uncorrected barometric height.	Pressure, un-corrected
102A	The standard temperature for the English scales is 62°F.; the standard temperature for the Metric scales is 0°C. The standard temperature for the density of mercury is 0°C. or 32°F. Since the scales and the mercury have different coefficients or expansion, the pressure indications will be affected by variations in temperature; therefore, in order to obtain the true pressure every reading must be corrected for temperature. The Temperature Correction Tables combines the corrections for length of the scales and the density of mercury.	Temperature correction factor
	Further, the pressure indication will be affected by the gravity of the place at which the reading is taken. Latitudes from 0° to 45° have a subtractive correction; latitudes from 46° to 90° have an additive correction. More precise	Gravity correction factor

Test Sequence	Test Description	Data Output
	determinations of the true pressure may be made by using the Gravity Correction Tables in conjunction with the observed readings corrected for temperature.	
	EXAMPLE; Assume the barometer reads 29.91" at a temperature of 75°F. Table 1 gives the temperature correction for every two degrees Fahrenheit and every one inch of atmospheric pressure. Interpolating, we find the correction to be -.125". The reading corrected for temperature, therefore, is 29.91" -.125', or 29.785". If the reading is being taken at a latitude of 42° the correction for gravity given in Table 2 is -.010" which makes the true pressure 29.785" -.010, or 29.775" which, if working to one hundredths of an inch, could be rounded off to 29.78".	
101B	After the aneroid barometers have attained equilibrium read the Fortin barometer and adjust the aneroid barometers at the corrected reading using the adjusting screw on the back of the barometer. Gently tap each gauge before taking the reading. Cover the adjusting screw with a piece of tape to discourage tampering.	Calib. Date Log Book Entry
101C	Correlation is accomplished by reading all the test cell barometers in their usual position once a week.	Log Book Entry By I.D. Number

TEMPERATURE CORRECTION TABLE — Table 1 — English System

To reduce the reading of the barometer to standard temperature

Temperature in Degrees F.	Observed Reading of the Barometer in Inches											
	20"	21"	22"	23"	24"	25"	26"	27"	28"	29"	30"	31"
	ALL CORRECTIONS SUBTRACTIVE											
60°	0.057	0.060	0.062	0.065	0.068	0.071	0.074	0.077	0.080	0.082	0.085	0.088
62	.060	.063	.066	.069	.073	.076	.079	.082	.085	.088	.091	.094
64	.064	.067	.070	.074	.077	.080	.083	.086	.090	.093	.096	.099
66	.068	.071	.074	.078	.081	.085	.088	.091	.095	.098	.101	.105
68	.071	.075	.078	.082	.085	.089	.093	.096	.100	.103	.107	.110
70	.075	.079	.082	.086	.090	.094	.097	.101	.105	.109	.112	.116
72	.078	.082	.086	.090	.094	.098	.102	.106	.110	.114	.118	.122
74	.082	.086	.090	.094	.098	.103	.107	.111	.115	.119	.123	.127
76	.086	.090	.094	.098	.103	.107	.111	.116	.120	.124	.128	.133
78	.089	.094	.098	.103	.107	.112	.116	.120	.125	.129	.134	.138
80	.093	.097	.102	.107	.111	.116	.121	.125	.130	.135	.139	.144
82	.096	.101	.106	.111	.116	.121	.125	.130	.135	.140	.145	.149
84	.100	.105	.110	.115	.120	.125	.130	.135	.140	.145	.150	.155
86	.104	.109	.114	.119	.124	.130	.135	.140	.145	.150	.155	.161
88	.107	.113	.118	.123	.129	.134	.139	.145	.150	.155	.161	.166
90	.111	.116	.122	.127	.133	.138	.144	.150	.155	.161	.166	.172
92	.114	.120	.126	.132	.137	.143	.149	.154	.160	.166	.172	.177
94	.118	.124	.130	.136	.142	.147	.153	.159	.165	.171	.177	.183
96	.122	.128	.134	.140	.146	.152	.158	.164	.170	.176	.182	.188
98	.125	.131	.138	.144	.150	.156	.163	.169	.175	.181	.188	.194
100	.129	.135	.142	.148	.154	.161	.167	.174	.180	.187	.193	.200

GRAVITY CORRECTION TABLE — Table 2 — English System

To reduce the reading of the barometer to standard gravity

Latitude	Observed Reading of the Barometer in Inches										
	20"	21"	22"	23"	24"	25"	26"	27"	28"	29"	30"
	LATITUDE 0° TO 45° THE CORRECTION IS TO BE SUBTRACTED LATITUDE 46° TO 90° THE CORRECTION IS TO BE ADDED										
0°	−0.054	−0.056	−0.059	−0.062	−0.064	−0.067	−0.070	−0.072	−0.075	−0.078	−0.080
5	.053	.055	.058	.061	.063	.066	.069	.071	.074	.077	.079
10	.050	.053	.055	.058	.060	.063	.066	.068	.071	.073	.076
15	.047	.049	.051	.053	.056	.058	.060	.063	.065	.067	.070
20	.041	.043	.045	.047	.050	.052	.054	.056	.058	.060	.062
25	.035	.037	.038	.040	.042	.043	.045	.047	.049	.050	.052
30	.027	.029	.030	.031	.033	.034	.035	.037	.038	.040	.041
32	.024	.025	.026	.028	.029	.030	.031	.032	.034	.035	.036
34	.021	.022	.023	.024	.025	.026	.027	.028	.029	.030	.031
36	.017	.018	.019	.020	.021	.022	.022	.023	.024	.025	.026
38	.014	.014	.015	.016	.016	.017	.018	.018	.019	.020	.020
40	.010	.011	.011	.012	.012	.013	.013	.014	.014	.015	.015
42	.006	.007	.007	.007	.008	.008	.008	.009	.009	.009	.010
44	−0.003	−0.003	−0.003	−0.003	−0.003	−0.003	−0.004	−0.004	−0.004	−0.004	−0.004
46	+0.001	+0.001	+0.001	+0.001	+0.001	+0.001	+0.001	+0.001	+0.001	+0.001	+0.001
48	.005	.005	.005	.005	.006	.006	.006	.006	.006	.007	.007
50	.008	.009	.009	.010	.010	.010	.011	.011	.012	.012	.012
55	.017	.018	.019	.020	.021	.021	.022	.023	.024	.025	.026
60	.026	.027	.028	.029	.031	.032	.033	.034	.036	.037	.038
65	.033	.035	.036	.038	.040	.041	.043	.045	.046	.048	.050
70	.040	.042	.044	.046	.048	.050	.052	.053	.055	.057	.059
75	.045	0.47	.049	.052	.054	.056	.058	.061	.063	.065	.067
80	.049	.051	.054	.056	.059	.061	.063	.066	.068	.071	.073
85	.051	.054	.056	.059	.061	.064	.067	.069	.072	.074	.077
90	+0.052	+0.055	+0.057	+0.060	+0.062	+0.065	+0.068	+0.070	+0.073	+0.075	+0.078

9.0 DATA INPUT

9.1 Enter calibration dates in log book by I.D. number. Indicate adjusted or not adjusted.

9.2 Enter the amount of deviation from true barometric pressure in the instrument log book.

10.0 DATA ANALYSIS

None required

11.0 DATA OUTPUT

11.1 A handwritten copy of the correlation data goes to Quality Assurance management.

12.0 ACCEPTANCE CRITERIA

12.1 In order to achieve 0.1% accuracy the barometer readings should correlate among themselves within ± 0.03 in. Hg.

12.2 Correlation should be established over 28.5 to 30.0 in. Hg. range.

13.0 QUALITY PROVISIONS

13.1 At the Factory the Fortin-Type Barometers are adjusted as nearly as possible to a zero correction by comparison with a certified standard. The adjustment is so made that no further correction for capillarity need be made.

EPA TEST PROCEDURE	Number TP-250	Page 1 of 4

SUBJECT

ENGINE DYNAMOMETER CALIBRATION

Reference	Data Form No. DYNO LOG BOOK
Responsible Organization CORRELATION AND MAINTENANCE	Computer Program
Test Witness SUPERVISOR - HEAVY DUTY TESTING	Performance Interval MONTHLY
Type of Test Report MAINTENANCE LOG BOOK ENTRY	Supersedes NEW
Report Distribution	Superseded by

REMARKS/COMMENTS

ORIGINAL RELEASE APPROVALS

Office	Section	Signature	Date
Administration	Quality Assurance		
Lab. Operator	Chief		
Corr. & Main.	Supervisor		
H D Testing	Supervisor		

REVISIONS

Change Letter	Description of Change	Approval	Date

REVISIONS:	ENGINE DYNAMOMETER CALIBRATION TEST PROCEDURE	PROCEDURE NO. TP-250 PAGE 2 OF 4

1.0 PURPOSE

This procedure outlines the method used for calibrating the engine dynamometer used for heavy duty engine emission testing.

2.0 TEST ARTICLE DESCRIPTION

2.1 G.E. Direct Current Dynamometer
600 h.p. MOD 426408AD

3.0 REFERENCES

3.1 Manufacturer's manual for operation of dynamometer and Unisystem controls

4.0 REQUIRED EQUIPMENT/CONDITIONS

4.1 Strobotac with the following specification:
accuracy ±1% of dial reading
Ranges: 110 - 690 RPM
670 - 4170
4000 - 25,000

4.2 Weights in 5 lb. increments as required by maximum torque rating of the dynamometer.

5.0 PRECAUTIONS

5.1 Dynamometer should not be coupled to an engine during calibration as damage could occur to an engine driven at excessive RPM by dynamometer.

5.2 Multiple images will be observed when stroboscope flashing rate is set to a multiple of the fundamental speed of the object. The operator should be sure that the flashing is set to a single image. The hub of the dyno may be marked to provide a visible reference.

5.3 When adding weights in increments the total weight should be determined each time by adding all of the individual weights.

6.0 VISUAL

6.1 Check oil level of dynamometer support trunnions.

7.0 TEST ARTICLE PREPARATION

7.1 Warm up dynamometer for 20 minutes at 2500 RPM.

7.2 Check calibration of Strobotac using line voltage frequency, synchronous motor or other method as recommended by electronic Stroboscope manufacturer.

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8.0 TEST PROCEDURE

Basically the procedure involves calibration of the speed read out device and the dynamometer torque bridge meter.

Test Sequence	Description	Data Output
	Speed Meter	
101	Set up Strobotac to illuminate hub of the dynamometer.	
102	Set strobotac frequency to indicate 2500, 2000 1500, 1000, and 500 RPM. Operate dyno at each set point until single image on dyno hub is noted. Record meter readout in dyno maintenance log book.	Log Book Entry Indicated RPM
103	If meter adjustment is required, adjust at 2000, RPM and repeat 500 2500 RPM readings. If meter is off at either end of the scale by more than 2% replace meter.	
104	Calibrate computer input and RPM recording device to match meter readings if required.	
	Torque Bridge	
201	Check zero reading of torque meter and computer input, adjust if required.	
202	Add sufficient weight to reach maximum rated torque according to the following: $\frac{\text{Max. Torque}}{\text{Arm Length}} = \text{Added Weight}$ Adjust meter and computer if required.	
203	Recheck zero and if adjustment is required repeat zero and max torque until no further adjustment is required.	
204	Starting at zero add weights in 10 lb increments until maximum reading is reached. Remove weights and observe readings, if different from initial reading repeat zero and maximum reading, record all observation in dyno maintenance log book.	Record Indicated vs Actual Torque
205	Calibrate torque recording device using torque meter as required.	

9.0 DATA INPUT

All observed readings recorded in the dynamometer maintenance log book.

10.0 DATA ANALYSIS

None required unless significant change noted from previous calibration.

11.0 DATA OUTPUT

Calibration results reported to quality assurance and heavy duty testing supervisor.

12.0 ACCEPTANCE CRITERIA

12.1 RPM and torque meter readings must agree within ±2% of calibrated value across measured range.

13.0 QUALITY PROVISIONS

13.1 Quality assurance periodically audits calibration procedure, reviews log book entries and determines acceptability of calibration procedure in the event of significant calibration variability.

13.2 Calibration of speed and torque performed monthly.

EPA TEST PROCEDURE	Number TP-251	Page 1 of 6

SUBJECT

CALIBRATION OF THE SMOKEMETER NEUTRAL DENSITY FILTERS

Reference FEDERAL REGISTER VOL. 37, P. 85.874-15 (A) (3)	Data Form No. HD251-01
Responsible Organization LABORATORY OPERATIONS - CHEMICAL ANALYSIS	Computer Program
Test Witness CERTIFICATION	Performance Interval AS REQUESTED
Type of Test Report CERTIFICATE FORM NO. 251-03	Supersedes NEW
Report Distribution CHEMICAL ANALYSIS - ORIGINAL COPIES: CERTIFICATION AND REQUESTOR	Superseded by

REMARKS/COMMENTS

ORIGINAL RELEASE APPROVALS

Office	Section	Signature	Date
LAB. OPER.	QUALITY ASSURANCE		
CHEM. ANALYSIS	SUPERVISOR		

REVISIONS

Change Letter	Description of Change	Approval	Date

1.0 PURPOSE

This procedure outlines the method used at the EPA Laboratories in Ann Arbor to calibrate and certify the opacity filters submitted by Manufacturers or Laboratories involved in the measurement of smoke emissions of diesel engines as required by Federal regulations.

2.0 TEST ARTICLE DESCRIPTION

A neutral density filter is an optical device which reduces the intensity of the light passing through it by the same percentage at all wavelengths. The reduction of light is linear across the entire color spectrum and thus, will not change the color of the light passing through it, only its intensity. The percent reduction in light intensity is called the opacity of the filter. The percent intensity of light which passes through the filter is referred to as the percent transmission.

Neutral density filters are used to check the calibration of smokemeters on the theory that diesel smoke is itself neutral. Most filters used are of the "sandwich" type composed of a filter material between two pieces of clear glass. Coated filters are available but should be avoided since cleaning and handling could damage this coating.

3.0 REFERENCES

3.1 Federal Register Vol. 37., P. 85.874-15 (a) (3) Dated November 15, 1972.

3.2 "Calibration of Neutral Density Filters", Cummins Technical Report No. 5425, R.B. Rich, May 9, 1972, Columbus, Indiana.

4.0 REQUIRED EQUIPMENT/CONDITIONS

4.1 Optical Bench - Spindler and Hayer, LA-3691.

4.2 Light Source - G.E. Microscope Illuminator - Nichrome Filament SR-8, Med. Base Down, ASA Code - EDS.

4.3 Voltage Regulator for light source.

4.4 Photomultiplier with case designed to eliminate stray light.

4.5 Digital voltmeter with accuracy of 0.1% of full scale.

4.6 Neutral density filters with NBS certified calibration.

4.7 Dark room with suitable temperature control and ventilation. Room is painted black to avoid possible unwanted stray light reflection.

4.8 Notebook for recording serial numbers of certified filters.

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5.0 PRECAUTIONS

5.1 No smoking is allowed in calibration room at any time as the smoke can coat the lenses and affect the calibration.

5.2 Care must be taken when handling filters. Hold only by metal ring or mounting. Fingerprints on the lenses could cause permanent damage.

6.0 VISUAL INSPECTION

6.1 Check optical system for dust, scratches, etc. prior to calibration check. Clean as required with isopropyl alcohol and lens tissue.

7.0 TEST ARTICLE PREPARATION

7.1 A serial number is assigned to each filter received and is etched on the ring or holder for identification by EPA. This should be done prior to calibration and the serial number information entered in the notebook.

7.2 Clean filters using Isopropyl alcohol and lens tissue taking care not to touch lens surfaces. Note: If lens is the "coated" type use only lens tissue and note on certificate "Coated lenses - cleaned with lens tissue only. Solvents may damage coating and should not be used for cleaning."

8.0 TEST PROCEDURE

After calibration check of the optical bench the lenses are inserted in the holder and compared by alternately inserting and removing from light path.

Test Sequence	Description	Data Output
101	Turn on light source, detector and DVM and allow to warm up for a minimum of two hours.	
102	Check to insure light beam is centered using target inserted in the holder. Turn off all room lights.	
103	Short out DVM and check zero reading. Adjust if required.	
104	Connect DVM to output of photomultiplier and adjust to approximately 100% transmission with no filter light in path.	
105	Repeat zero check (103.)	
106	Check calibration with neutral density filters having nominal values of clear, 0.15 and 0.4 opacity. Reading should agree within 0.5% of NBS calibrated value. If any or all readings are out of specification, optical bench alignment must be checked and calibration performed using all available filter standards.	

NBS Traceable Standards

Serial No.	Nominal Opacity	Actual % Transmission
______	Clear	91.54
______	0.1	80.35
______	0.15	75.04
______	0.4	43.88
______	0.5	29.68

Enter all data on Form Number HD-251.02

Date
Run By
Run No.
I, I_o, T

8.0 TEST PROCEDURE

After calibration check of the optical bench the lenses are inserted in the holder and compared by alternately inserting and removing from light path.

Test Sequence	Description	Data Output
101	Turn on light source, detector and DVM and allow to warm up for a minimum of two hours.	
102	Check to insure light beam is centered using target inserted in the holder. Turn off all room lights.	
103	Short out DVM and check zero reading. Adjust if required.	
104	Connect DVM to output of photomultiplier and adjust to approximately 100% transmission with no filter light in path.	
105	Repeat zero check (103.)	
106	Check calibration with neutral density filters having nominal values of clear, 0.15 and 0.4 opacity. Reading should agree within 0.5% of NBS calibrated value. If any or all readings are out of specification, optical bench alignment must be checked and calibration performed using all available filter standards.	

NBS Traceable Standards

Serial No.	Nominal Opacity	Actual % Transmission
______	Clear	91.54
______	0.1	80.35
______	0.15	75.04
______	0.4	43.88
______	0.5	29.68

Enter all data on Form Number HD-251.02

Date
Run By
Run No.
I, I_o, T

8.0 TEST PROCEDURE (Continued)

Test Sequence	Description	Data Output
107	Check filter to be tested for scratches or other marks and record on Certificate Form No. HD-251-03.	
108	Insert into holder, out of beam, note light intensity on DVM and record. When stable, signal computer (K400) to read for 20 seconds.	I_o
109	Insert holder with filter into light beam and note DVM reading. When stable, signal computer (K400) to read for 20 seconds.	I
110	Record above reading on Data Sheet HD-251-01.	I_o, I
111	Repeat sequences 108 and 109 twice more.	I_o, I
112	Computer will calculate percent transmission using the average of the three readings by $\frac{I}{I_o} \times 100 = \% T$ % of Opacity = 100 - % T where I_o = open beam reading (incident light) I = filter reading (transmitted light)	
113	Enter filter number, date of calibration and % transmission on Form No. HD-251-03. Certificate signed by Supervisor - Chemical Analysis Department. Note: Check if filter has previously assigned serial number and enter "recalibration" on Form No. HD-251-03.	No. Date % T

9.0 DATA INPUT

9.1 Three separate readings of I and Io are made and read by the computer.

10.0 DATA ANALYSIS

11.1 Original certificate (Form No. HD-251-03) kept by Chemical Analysis Department in file. Copy sent to Certification with filters and copy of completed work order.

12.0 ACCEPTANCE CRITERIA

12.1 Calibration must agree within 0.5% of NBS value.

12.2 Test filter Io and I readings must agree within ±0.5%.

13.0 QUALITY PROVISIONS

13.1 Neutral density filters used for calibration must be sent to NBS for recalibration every 6 months.

13.2 Complete calibration check must be repeated if out of specifications and after optical alignment.

13.3 If readings are not repeated within specified tolerance repeat calibration and test.

13.4 Data on computer print out and form must agree within 0.2 units. If they do not agree repeat test after checking alignment of DVM and computer.

13.5 If filter has been previously calibrated by EPA, compare previous readings. Normally they should agree within 1% if calibration interval is not greater than 1 year. If greater than 1%, note on lab order request.

FILTER CALIBRATION

Form No. HD-251-01

TR-251
Attachment No. 1

Date____________________

Owner______________________________

Resistor_________________

Filter No._______________

Run No._________________

	Run 1	Run 2	Run 3	Remarks
Io				
I				
Io				
I				
Io				
I				
Ave.				Io = Open Beam
$\frac{I}{Io}$	______	______	______	I = Sample filter in beam
T				T = % Transmission

BENCH CALIBRATION EPA Form No. HD-251-02 TP-251
Attachment No. 2

Date ____________________

Run No. ____________________________ Resistor ______________

Run By ________________

	Clear	ND .1	ND .15	ND .4	ND .5	1 Round	2 Round
Io							
I							
Io							
I							
Io							
I							
$\frac{I}{Io}$	______	______	______	______	______	______	
T							

Form No. HD-251-03

TP-251
Attachment No. 3

ENVIRONMENTAL PROTECTION AGENCY

OFFICE OF AIR AND WASTE MANAGEMENT

Certificate of Certification
For Neutral Density

Filter Number ______________________________

Date of Calibration ____________________

N.D. ______________

Transmission ± 1%

This is to certify that the above named filter has been checked and found to have the transmission value indicated. A procedure prescribed by the Procedures Development Branch of the Environmental Protection Agency, Office of Air and Waste Management was used, and is traceable to standard procedures for photometric measurements as prescribed by the National Bureau of Standards.

Certified by ______________________________

on this the _______ day of ___________ 19____

____
Owner

Section 300

VERIFICATION

EPA TEST PROCEDURE

Number TP-304

Page 1 of 5

SUBJECT

CARBON DIOXIDE AND WATER INTERFERENCE
CHECK FOR THE NDIR CARBON MONOXIDE ANALYZER

Reference FEDERAL REGISTER, VOL 38, November 15, 1973, 85.075-23, (a)(7)(iii)

Data Form No. 304-01

Responsible Organization CORRELATION AND MAINTENANCE

Computer Program NONE

Test Witness/Review TEAM LEADER, QUALITY ASSURANCE

Performance Interval See Below

Type of Test Report INITIAL EQUIPMENT CHECKOUT OR WEEKLY CHECK

Supersedes New

Report Distribution QUALITY ASSURANCE, CORRELATION AND MAINTENANCE, TEST OPERATION

Superseded by

REMARKS/COMMENTS

1. If the CO-NDIR meets the requirements of 85.075-20 (C)(11) without the conditioning columns the test is performed to demonstrate conformance to the criteria when the instrument is first put into service.

2. If the instrument does not meet the above criteria conditioning columns must be used and checked weekly or as determined by average column life.

ORIGINAL RELEASE APPROVALS

Office	Section	Signature	Date
Program Mgmt	Quality Assurance		
Lab Branch	Test Operations Chief		
Lab Branch	Support Oper Chief		

REVISIONS

Change Letter	Description of Change	Approval	Date

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1.0 PURPOSE

To establish conformance with the interference requirements of 85.075-20(c)(11) with new instrument trains or to assure the proper operation of those trains requiring conditioning columns for removal of CO_2 and water vapor.

2.0 TEST ARTICLE DESCRIPTION

The carbon monoxide analyzers are of the non-dispersive infrared type. Certain instruments available from vendors employ an internal optical filtering mechanism to eliminate the interference from CO_2 and water vapor.

Instruments that are not free of interference must use sample conditioning columns consisting of calcium sulfate or indicating silica gel to remove water vapor and ascarite to remove carbon dioxide.

3.0 REFERENCES

3.1 Federal Register, Vol. 38, Nov 15, 1973 85.075-23(a)(7)(iii)
Federal Register, Vol. 39, No. 101, May 23,1974 85.075-20(c)(11)

4.0 REQUIRED EQUIPMENT

4.1 Gas bubbler, sized for the flow rate used for the interference check.

4.2 Calibration gas, 3 percent carbon dioxide in nitrogen. Make tolerance on the blend should be within ±5% and the analysis for CO_2 ±2%. When ordering this blend the concentration of the CO impurity should be requested not to exceed 1 ppm and/or determined by receiving inspection.

4.3 Zero Air

4.4 Zero Nitrogen

4.5 A portable manifold with selector valves for introducing the above gases individually, wet and dry.

4.6 A hopcolite filter for removing CO from the zero air to establish a true instrument zero.

5.0 PRECAUTIONS

5.1 If a glass bubbler is used it should not be subjected to pressure above 2 PSI.

5.2 The bubbler should be contained or shielded to protect the operator in case of explosion (i.e., overpressurization or sudden surge in the glass bubbler).

5.3 Flow rates are important and should be closely controlled.

5.4 Extreme care should be taken not to introduce any water droplets or aerosol into the train or analyzer.

5.5 Leak check the manifold before each use by turning off each cylinder valve and observing any drop in regulator pressure.

6.0 VISUAL INSPECTION

6.1 Check ascarite and silica gel columns for color change, contamination, and clogging, etc., indicating need for replacement.

6.2 Check water level of the bubbler.

7.0 TEST ARTICLE PREPARATION

7.1 The CO analyzer should be on for at least 2 hours prior to test.

REVISIONS:	CO_2/H_2O INTERFERENCE CHECK NDIR-CO **TEST PROCEDURE**	**PROCEDURE NO.** TP-304 **PAGE** 4 **OF** 5

8.0 TEST PROCEDURE

Test Sequence	Test Description	Data Output
101	Zero instrument using zero air passed through the hopcolite to remove the CO using normal train flow rate and pressure.	Zero
102	Pass zero nitrogen through instrument to establish nitrogen zero. Use this reading for all subsequent nitrogen zeros.	Zero & CO Impurity
103	Span instrument on lowest range using same flow rate as zero flow rate.	Span Deflection
104	Repeat nitrogen zero and span until stability is reached.	Span Deflection
105	Pass zero nitrogen through water bubbler and analyzer at same flow rate.	Water vapor deflection minus N_2 zero
106	Bypass water bubbler and repeat nitrogen zero	Zero & CO Impurity
107	Bypass water bubbler and introduce 3% CO_2 gas into instrument. NOTE: If CO impurity in the CO_2 gas is less that in the nitrogen the reading may be less than the nitrogen zero deflection.	Dry CO_2 deflection
108	Repeat nitrogen zero.	
109	Pass 3% CO_2 thru water bubbler into instrument at same flow rate as the other gases	Wet CO_2 Deflection
110	Repeat nitrogen zero.	
111	Disconnect manifold, turn off cylinders, relieve regulator pressures.	

REVISIONS:	CO_2/H_2O INTERFERENCE CHECK NDIR-CO **TEST PROCEDURE**	**PROCEDURE NO.** TP-304 **PAGE** 5 **OF** 5

9.0 DATA INPUT

9.1 Complete form #304-01

10.0 DATA ANALYSIS

10.1 Instrument response comparison.

11.0 DATA OUTPUT

11.1 Interference levels for CO_2 and H_2O vapor.

12.0 ACCEPTANCE CRITERIA

12.1 The wet CO_2 reading on any range above 300 ppm must be less than 1% of full scale; on ranges below 300 ppm the interference must be less than 3 ppm.

13.0 QUALITY PROVISIONS

13.1 If the instrument does not meet acceptance criteria initiate corrective action.

13.2 Repeat the procedure to assure corrective action was successful.

CO_2/H_2O INTERFERENCE CHECK

Analyzer Model ________ Serial # ________

Date ________________ Time ____________

1. ☐ Zero Instrument
2. ____________ Nitrogen zero set point
3. ____________ Span deflection (repeat 2 times)
4. ____________ H_2O vapor deflection
5. ☐ Nitrogen zero (bypass bubbler)
6. ____________ Dry CO_2 deflection
7. ____________ Wet CO_2 deflection

Operator signature ____________________

Form 304-01

Section 400

CORRELATION

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EPA TEST PROCEDURE	Number TP-401	Page 1 of 4

SUBJECT ANALYZER CROSSCHECK	
Reference EPA, ANN ARBOR, "PREVENTIVE MAINTENANCE GUIDELINES."	Data Form No. 401-01
Responsible Organization CORRELATION/MAINTENANCE	Computer Program
Test Witness /Review CORRELATION/MAINTENANCE LEADER, QUALITY ASSURANCE	Performance Interval DAILY
Type of Test Report	Supersedes NEW
Report Distribution QUALITY ASSURANCE, TEST OPERATIONS, CORRELATION & MAINTENANCE	Superseded by

REMARKS/COMMENTS

ORIGINAL RELEASE APPROVALS

Office	Section	Signature	Date
Program Mgmt	Quality Assurance		
Lab Branch	Chief		
Lab Branch	Test Operations Chief		
Lab Branch	Support Services Chief		

REVISIONS

Change Letter	Description of Change	Approval	Date

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REVISIONS:	ANALYZER CROSSCHECK **TEST PROCEDURE**	PROCEDURE NO. TP-401 PAGE 2 OF 4

1.0 PURPOSE

To assure the correlation of multiple analyzer trains used for exhaust sample analysis.

2.0 TEST ARTICLE DESCRIPTION

2.1 Gas Analysis System equipped with the following analyzers

2.1.1 Hydrocarbon - flame ionization

2.1.2 Carbon monoxide - non-dispersive infrared

2.1.3 Carbon dioxide - non-dispersive infrared

2.1.4 Oxides of Nitrogen - Chemiluminescence

3.0 REFERENCES

3.1 EPA, Ann Arbor, "Preventive Maintenance Guidelines"

4.0 REQUIRED EQUIPMENT

4.1 Composite bag sample collected from a non-test vehicle or an artificial blend from span gases.

5.0 PRECAUTIONS

5.1 Sample bag should be leak checked.

5.1.1 (Short method) Fill the bags with background air and draw through the sample system. If flow indication drops to zero the bags are good, if not replace bag.

6.0 VISUAL INSPECTION

6.1 Check flow and pressure settings prior to and during bag analysis.

7.0 TEST ARTICLE PREPARATION

7.1 Perform daily start-up on each system to be checked.

7.2 Zero and span each analyzer prior to analysis.

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REVISIONS:	ANALYZER CROSSCHECK **TEST PROCEDURE**	**PROCEDURE NO.** TP-401 **PAGE** 3 **OF** 4

8.0 TEST PROCEDURE

The analyzer crosscheck is performed in the following manner.

Test Sequence	Test Description	Data Output
101	Fill a sample bag with enough composite vehicle exhaust to perform the crosscheck analysis on a minimum of 4 systems. (Approximately 3.0 cubic feet.)	
102	A representative from Correlation/Maintenance will carry the sample to the first train to be checked.	
103	The analyzer operator will analyze the collected sample in accordance with the specified analysis procedure (TP-707).	
104	The C/M rep. will collect the analyzer traces and mark the train number on each trace.	
105	The sample is taken to the remaining trains and steps 103 and 104 are repeated for each.	

9.0 DATA INPUT

9.1 Data is transcribed onto data sheet #401-01.

9.2 A complete set of analyzer traces are collected from each train, including the sample concentration.

10.0 DATA ANALYSIS

10.1 The concentration for each pollutant HC, CO, CO_2 and NO_x is computed from the analyzer traces for each train checked by computer program.

10.2 The concentrations from each train are then compared for any results outside of repeatable limits.

11.0 DATA OUTPUT

11.1 The average values and percent deviation (if any) of each train.

12.0 ACCEPTANCE CRITERIA

12.1 Results from the crosscheck should repeat by ±3 percent between each system checked.

13.0 QUALITY PROVISIONS

13.1 If "out of spec" conditions (see 12.1) exist corrective action will be initiated.

FORM NO. 401-01

ANALYZER CORRELATION DATA SHEET

Date: ____/____/____

Barometer: __________"HG.

		ZERO/SPAN DATA						CALCULATED CONCENTRATION				% DEVIATION				
Train NO.	Gas Type	Rge. NO.	Conc.	Set Point	Zero Gain	Span Gain	Sample Deflc	HC	CO	CO_2	NO_x	HC	CO	CO_2	NO_x	OPERATOR
9	HC				—	—										
	CO															
	CO_2															
	NO_x				—	—										
15	HC				—	—										
	CO															
	CO_2															
	NO_x				—	—										
16	HC				—	—										
	CO															
	CO_2															
	NO_x				—	—										
19	HC				—	—										
	CO															
	CO_2															
	NO_x				—	—										
21	HC				—	—										
	CO															
	CO_2															
	NO_x				—	—										
	HC															
	CO															
	CO_2															
	NO_x				—	—										
AVERAGE VALUES																

Section 500

MAINTENANCE

Currently no procedures are included in this section of the manual. Procedures pertaining to this section must be supplied by the user and may be supplied by the EPA in subsequent revisions.

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Section 600

DAILY OPERATION

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EPA TEST PROCEDURE

Number
TP-601

Page 1 of 4

SUBJECT

OPERATION, MAINTENANCE AND INSTRUMENTATION LOG BOOK ENTRY PROCEDURES

Reference EPA, ANN ARBOR "PREVENTIVE MAINTENANCE GUIDELINES" LOG BOOK	Data Form No. LOG BOOKS
Responsible Organization CORRELATION/MAINTENANCE, TEST OPERATIONS, INSTRUMENT SERVICES	Computer Program NONE
Test Witness /REVIEW INST. SERVICES LEADER CORR. & MAINT. LEADER, TESTING, TEAM LEADER	Performance Interval DAILY & WHEN NECESSARY
Type of Test Report LOG BOOK ENTRY	Supersedes NEW
Report Distribution Q.A., TEST OPERATIONS, CORRELATION MAINT., INST. SERVICES	Superseded by

REMARKS/COMMENTS

ORIGINAL RELEASE APPROVALS

Office	Section	Signature	Date
PROGRAM MGMT.	QUALITY ASSURANCE		
LABORATORY BRANCH	CHIEF		
LABORATORY BRANCH	TEST OPERATIONS CHIEF		
LABORATORY BRANCH	SUPPORT SERVICES CHIEF		

REVISIONS

Change Letter	Description of Change	Approval	Date

Preceding page blank

REVISIONS:	LOG BOOK ENTRY PROCEDURES **TEST PROCEDURE**	PROCEDURE NO. TP-601 PAGE 2 OF 4

1.0 PURPOSE

To record all malfunctions, breakdowns and other items related to the CVS, Analysis System, and dynamometers that are pertinent in effecting proper maintenance and repair of each.

2.0 TEST ARTICLE DESCRIPTION

2.1 All test and measurement equipment.

3.0 REFERENCES

3.1 EPA, Ann Arbor, "Preventive Maintenance Guidelines."

4.0 REQUIRED EQUIPMENT

4.1 Log Book.

5.0 PRECUATIONS

5.1 Insure that all entries explain the problems/solutions thoroughly.

6.0 VISUAL INSPECTION

6.1 Log book entries will be checked before each weekly and monthly calibration/check-out period.

7.0 TEST ARTICLE PREPARATION

None required.

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REVISIONS:	LOG BOOK ENTRY PROCEDURES **TEST PROCEDURE**	**PROCEDURE NO.** TP-601 **PAGE** 3 **OF** 4

8.0 TEST PROCEDURE

In order to make clear, concise log book entries the following steps should be followed.

Test Sequence	Test Description	Data Output
101	Log the date and time of malfunction or repair and the responsible technician's initial.	Date, time
102	Identify the system or individual equipment item.	Item
103	In clear terminology state the problem encountered and repair made.	
104	If the log entry is a malfunction or maintenance description, log time and date that Correlation/ Maintenance or Instrument Services was notified. Also identify the person notified.	
105	If the entry is a repair item, state all maintenance performed, and the date and time back on line. The initials of the person responsible for the maintenance or corrective action should be shown.	Initials of responsible party

9.0 DATA INPUT

9.1 Record all pertinent items in the appropriate Log Book.

10.0 DATA ANALYSIS

10.1 A malfunctioning item can usually be diagnosed and repaired more efficiently if all aspects of the failure are known.

10.2 Daily readings of pressure and temperature of the CVS should be checked to assure repeatability from day to day.

11.0 DATA OUTPUT

11.1 Log Book becomes a permanent record of all malfunctions and repair of equipment.

12.0 ACCEPTANCE CRITERIA

N/A

13.0 QUALITY PROVISIONS

13.1 Entries shall be checked on an audit basis and data compiled on all malfunctions and repairs.

13.2 Frequency of maintenance actions shall be compiled by checking the Log Books.

13.3 Audits of the Log Book will also indicate typical maintenance/repairs of test and measurement equipment.

TP-601
Attachment No. 1

INSTRUMENT SERVICES LOG BOOK

MAKE	MODEL	SERIAL NO.	DATE CALIBRATED	DATE DUE	TECH.	REMARKS
ESTERLINE	E1124E	940456	8-29-74	11-29-74	D.P	REPLACED INK PAD & PRINT WHEEL
"	"	940757	10-11-74	1-11-75	D.P.	1° LOW PRIOR TO CAL.
HONEYWELL	194 E	5103576E	12-7-74	3-7-75	J.J	GAIN HIGH PRIOR TO CAL
TEX. INSTR.	2596-2	T135701	12-9-74	3-9-75	J.J	REPLACED SLIDE WIRE

ANALYZER LOG

DATE	INSTRU. TYPE	GAIN	TUNE	MAINTENANCE/REMARKS	OPER. INITIALS

CVS OPERATION LOG

DATE	IN. PRESS.	OUT. PRESS.	CVS HOURS	COUNTS: 505	867	505	REMARKS	OPER. INITIALS

EPA TEST PROCEDURE

Number TP-602

Page 1 of 4

SUBJECT

DRIFT/NOISE/GAIN/TUNE CHECKS

Reference SEE SECTION 3.0	Data Form No. ANALYZER OP LOG BK
Responsible Organization CORRELATION/MAINTENANCE, ANALYZER OPERATION	Computer Program NONE
Test Witness/Review ANALYZER OPERATOR, TEAM LEADER	Performance Interval DAILY
Type of Test Report ANALYZER LOG BOOK ENTRY	Supersedes NEW
Report Distribution QUALITY ASSURANCE, CORRELATION AND MAINTENANCE	Superseded by

REMARKS/COMMENTS

ORIGINAL RELEASE APPROVALS

Office	Section	Signature	Date
Program Mgmt	Quality Assurance		
Lab Branch	Chief		
Lab Branch	Supp Services Chief		
Lab Branch	Test Operations Chief		

REVISIONS

Change Letter	Description of Change	Approval	Date

1.0 PURPOSE

To perform a daily check of the analyzers and recorders used in the analysis system.

2.0 TEST ARTICLE DESCRIPTION

2.1 An analysis system equipped with the following analyzers.

2.1.1 Hydrocarbons - Flame ionization

2.1.2 Carbon monoxide - NDIR (non-dispersive infrared)

2.1.3 Carbon dioxide - NDIR

2.1.4 Oxides of Nitrogen - Chemiluminescence

2.2 Strip chart recorders

3.0 REFERENCES

3.1 EPA, Ann Arbor, Training Manual, "Light Duty Certification Procedures"

3.2 EPA, Ann Arbor, "Preventive Maintenance Guidelines"

4.0 REQUIRED EQUIPMENT

4.1 "Working" span gases

4.2 Zero air or nitrogen gases

5.0 PRECAUTIONS

5.1 If any discrepant conditions are observed the analyzer operator shall not attempt any repair or adjustment. The condition shall be reported to Correlation/Maintenance and/or Instrument Services for investigation and disposition.

6.0 VISUAL INSPECTION

See Section 8.0

7.0 TEST ARTICLE PREPARATION

7.1 The instruments shall be warmed up to stable operating conditions (as per individual manufacturer's requirements)

REVISIONS:	DRIFT/NOISE/GAIN/TUNE CHECKS **TEST PROCEDURE**	**PROCEDURE NO.** TP-602 **PAGE** 3 **OF** 4

8.0 TEST PROCEDURE

The following steps are to be accomplished to check the efficiency of the analyzers and recorders.

Test Sequence	Test Description	Data Input
101	Zero drift is checked in the following manner.	
A	o Introduce zero gas into the analyzer	
B	o Adjust the analyzer to read zero millivolts and set the chart recorder on zero	
C	o Allow zero gas to flow for approximately 5 to 10 min.	
D	o From the strip chart determine the difference between the highest and lowest value of the zero trace.	
E	o Record difference as C	C
102	Excessive noise is indicated on the chart recorder by signal spiking. NOTE: Noise may be caused by the recorder or the analyzer, therefore the gain adjustment of the recorder should be checked.	Noise
103	The gain setting should be checked daily to assure a major shift has not occurred. Record the analyzer gain setting and check reading from following day. Record percent change.	Gain set., % change
103A	If the chart recorder is insensitive or oversensitive to small changes in input signals (0.50% of full scale), record the problem in the log book.	Recorder gain
104	If a normal operating span point cannot be reached, or a negative read-out is indicated when a span gas is introduced to an analyzer, record out of tune. Document the type of response in the log book. (Instrument Services and/or Correlation will make final decision to the type of problem encountered)	Out of tune

REVISIONS:	DRIFT/NOISE/GAIN/TUNE CHECKS **TEST PROCEDURE**	PROCEDURE NO. TP-602 PAGE 4 OF 4

9.0 DATA INPUT

9.1 Record any drift, noise, gain or tune problems in the Analyzer log book (attachment A).

10.0 DATA ANALYSIS

10.1 Determine if the problem recorded is an analyzer or recorder malfunction by comparing historical readings in the analyzer log book.

10.2 Determine if the problem is of sufficient magnitude to warrant maintenance.

11.0 DATA OUTPUT

11.1 Enter results in the analyzer log and history file.

12.0 ACCEPTANCE CRITERIA

12.1 Drift should not exceed ±1% of full scale

12.2 Noise should not exceed ±1% of full scale

12.3 Shifts in gain settings should not exceed ±1% in any 24 hour period.

12.4 Compare readings to those in the analyzer log.

13.0 QUALITY CONTROL PROVISIONS

13.1 If problem warrants maintenance submit a corrective action request.

13.2 Prepare and maintain control charts for future analysis.

TP-602
Attachment No. 1

ANALYZER LOG

DATE	INSTRU. TYPE	GAIN	TUNE	MAINTENANCE/REMARKS	OPER. INITIALS

Section 700

EMISSION TESTING

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EPA TEST PROCEDURE	Number TP-750	Page 1 of 7

SUBJECT

RECEIPT, BUILD-UP AND INSTALLATION OF THE DIESEL TEST ENGINE

Reference MSAPC ADVISORY CIRCULAR NO. 22A 4/3/73	Data Form No.
Responsible Organization HEAVY DUTY TEST OPERATIONS	Computer Program NONE
Test Witness HD - TEST SUPERVISOR	Performance Interval EACH ENGINE
Type of Test Report CHECK LIST	Supersedes NEW
Report Distribution CERTIFICATION - TEST OPERATIONS - DATA FILE	Superseded by

REMARKS/COMMENTS

ORIGINAL RELEASE APPROVALS

Office	Section	Signature	Date
Lab. Oper.	Quality Assurance		
Test Oper.	Chief		
HD Testing	Supervisor		
Certification	Heavy Duty		

REVISIONS

Change Letter	Description of Change	Approval	Date

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1.0 PURPOSE

Outlines the proper procedure for receiving inspection and proper installation of engine received for emission testing.

2.0 TEST ARTICLE DESCRIPTION

Heavy duty diesel engines are shipped to the EPA for certification or other emission tests. These engines are prepared for testing by the Manufacturer according to the prescribed procedure in MSAPC Advisory Circular No. 22A.

3.0 REFERENCES

3.1 MSAPC Advisory Circular No. 22A dated April 3, 1973.

3.2 Federal Register, paragraphs 85.874-12 and 85.974-12.

4.0 REQUIRED EQUIPMENT/CONDITIONS

4.1 Small tools and necessary plumbing, thermocouple connectors etc., necessary for installation. See Section 8.0 for more detail.

5.0 PRECAUTIONS

5.1 Care should be taken when unloading the engine to place the forks or other lifting device properly to prevent damage to engine or components.

5.2 Engine should not be lifted nor moved by any part of the engine except by those means provided by the manufacturer, such as bed plate pallet, engine mounts, etc.

5.3 Never start the engine without first checking all installation connections and alignment.

6.0 VISUAL INSPECTION

6.1 Receiving - Check engine for proper packaging and unloading requirements. After unloading, check for proper shipping documents and markings. Check for any signs of damage to shipping container and engine.

6.2 Build-up - Check engine for specified temperature, cooling, fuel, drive shaft, and pressure connections.

6.3 Installation - Check for proper coolant and oil level, distance from centerline of shaft to bed plate, engine lag down bolts.

7.0 TEST ARTICLE DESCRIPTION

See Sections 6.0 and 8.0 for preparation procedures.

8.0 TEST PROCEDURE

Test Sequence	Description	Data Output
101	Unload from truck using fork lift. Verify shipping weight does not exceed lift capacity.	Check Sheet HD-750-01
102	Fill out HD-receipt form. Explain all deficiencies. List all parts, number of shipping containers, shipping markings, other identifying marks and pertinent information.	Receiving Inspection Form No. HD-750-02
103	Build-up and Install. o Thermocouple (s) o Water Hose (s) o Drive Shaft Check adapter plate bolts o Oil Pressure Line o Fuel Feed Line and Return Line o Fuel Pressure Line o Manifold Pressure Line	Check Sheet
104	Check oil level (fill if required), distance from centerline of shaft to bed plate, engine lag down bolts.	Check Sheet
105	Move engine to test cell and install on the test bed using the following sequence. o Prepare engine test bed to receive engine and pre-aligned stand o Lift engine onto bed with hoist and bolt it in place o Bolt coupling to dynamometer and engine shaft; connect fuel and coolant systems using hand tools (refer to appropriate manufacturer's requirements for specifications) o Install inlet air restriction device to provide restrictions of ±1" H_2O of upper limits of engine operation which gives maximum air flow o Connect thermocouples and pressure gauges o Check engine for completeness, engine mounting, and engine alignment	Check Sheet

8.0 TEST PROCEDURE (CONTINUED)

Test Sequence	Description	Data Output
105	o Determine necessary exhaust system (including muffler) with final results of: 1. Exhaust back pressure to be within ±0.2"Hg at maximum rates HP 2. Overall length of exhaust pipe to be 15 feet ± 5 feet 3. Final two feet of pipe to be straight and round and to size specified for rated BHP o Fabricate exhaust system and install, making provisions for probe location o Install intake airflow measuring system and leak check same o Verify compliance maintenance procedures.	
106	Engine - Dynamometer check out. After careful inspection of the installation, the engine is run to make adjustments.	
	o Using test cell dynamometer check list confirm that all the necessary connections have been made, instruments and equipment properly installed, and all controls are properly set prior to engine start up	Check List HD-750-03
	o Check safety interlock system for proper installation o Check throttle no-load, full-load positioning o Check oil and water for proper level o Check operation of system safety interlocks o Start engine and perform visual, audio, and functional inspection Listen for internal noises, such as piston slap, knocks, taps and gear noises that indicate irregularities in engine operation Check for fuel and lubricant leaks, check for exhaust and crankcase emission leaks o Bring engine to rated load and speed in gradual steps o Use manufacturer's recommended procedure for adjusting air and exhaust restrictions. Inlet air restriction should be ± 1" H_2O of maximum specified by manufacturer.	

8.0 TEST PROCEDURE (CONTINUED)

Test Sequence	Description	Data Output
106 (cont'd)	o Exhaust restriction should be ± 0.2" Hg of upper limit specified by manufacturer Determine when engine conditions have stabilized and record BHP and fuel rate	BHP
	o Determine when engine conditions have stabilized and record BHP and fuel rate	Fuel Rate
	o Lug engine to peak torque speed and record torque and fuel rate	
	o Check engine performance for compliance with manufacturer's specifications; if non-compliance is noted, contact supervisor	
	o Shut down engine and dynamometer systems and record time and ambient temperature	
	o Fill out request for repairs if necessary	
	o All pretest functions should be completed with a minimum amount of engine running time	
107	Preparation of test engine for return to Manufacturer	Check List (Form HD-750-04)
	o Disconnect:	
	o Drive Shaft - Both Ends,	
	o Engine Stand Lag Down Bolts	
	o LFE - Diesel, only	
	o Accessory Stands	
	o Exhaust System at exhaust manifold only	
	o All temperature thermocouple wires from Control Room assembly	
	o All sample probe lines from engine only	
	o All fuel, oil, vacuum, manifold, pressure and feed lines from Control Room assembly only	
	o Oil coolant hoses from Coolant package	
	o Move Engine and Exhaust System	
	o Diesel Engine (s) to Room 319	
	o Disconnect	
	Remove and put in proper place	

8.0 TEST PROCEDURES (continued)

Test Sequence	Description	Data Output
107 (cont'd)	o All thermocouples, wires and fitting (if installed by E.P.A.) o Water Hoses o Drive Shaft o All fuel, oil, vacuum, manifold, pressure and feed lines and fittings	
	o Drain	
	o Follow manufacturer's recommended procedure for draining coolant Drain oil if necessary	
	o Re-Install	
	o Exhaust System and all other engine parts and accessories received	
	NOTE: Check HD Receiving form to assure shipment is complete as received	
108	Complete Shipping Order No. HD-750-05	

9.0 DATA INPUT

9.1 Check sheets validated by supervisor and place into test file.

10.0 DATA ANALYSIS

None

11.0 DATA OUTPUT

None

12.0 ACCEPTANCE CRITERIA

12.1 Engine as received must conform to specifications outline in MSAPC Advisory Circular No. 22A (4-3-73).

12.2 Inlet and outlet restrictions must conform to specifications noted in test procedure.

12.3 Engine must conform to manufacturer's specifications.

12.4 Engine must not exhibit any malfunctions such as oil leaks, engine noise, erratic running or overheating.

13.0 QUALITY PROVISIONS

13.1 Engine returned to manufacturer if all specifications not met.

13.2 Engine installation approved by supervisor and certification engineer.

13.3 Data validation inspects check lists for discrepancies and completeness.

13.4 Discrepancies noted during receiving inspection reported to supervisor and quality assurance.

TP-750
Attachment No. 1

Check List Receipt, Build-up and Installation Diesel Test Engine

Description		Oper. Init.
Unload from truck		
Visual Inspection:	Fill out HD-receipt form	
	Explain all deficiencies	
Description	List all parts	
Build-up and Install:	Temperature Thermocouple (s)	
	Water Hose (s)	
	Drive Shaft (check adaptor plate bolts)	
	Oil Pressure Line	
	Fuel Feed Line	
	Fuel Pressure Line	
	Fuel Solenoid Line	
	Manifold Pressure Line	
Check:	Oil Level (fill if required)	
	Distance C/L shaft to bed plate	
	Engine Lag Down Bolts	
Move to test cell:	Center engine stand on bed plate and lag down	
Connect:	Temperature Thermocouple (s)	
	Water Hoses	
	Drive Shaft	
	Oil Pressure Line	
	Fuel Feed Line	
	Fuel Pressure Line	
	Manifold Pressure Line	
	Fuel Solenoid	
	Accelerator Actuator	
	Exhaust System	
	Exhaust Sample Probes	
	Restrictor Valves	
	Air Cleaner	
	Sample Probes	
	Smoke Metering Equipment	

Form HD-750-01

Date ______________________ **Manufacturer** ______________________

Engine C.I.D. ______________ Engine I.D.# ______________________

Test Type Cert. ____ Dura. ____ Correl. ____ Other ____

# Pieces ______________________

Description ____

____

Condition ____

____

Received by ____

____

Test Date ______________________ Test # ______________________

EPA EPA

HC ______________________ Accel. ______________________

CO ______________________ Lug ______________________

NO_x ______________________

Manufacturer's Rep. Signature ______________________________

Certification Rep. Signature ______________________________

Returned Date ______________________________

Form HD-750-02 - Receiving Inspection Report

TP-750
Attachment No. 3

Check List Test Cell 1 and 2
Diesel Engine Dynamometer Operation

Check: **Water Cooler Package:** Oper. Init.

Water ON ________
Expansion Tank - 2/3 to 3/4 full ________
Pump ON ________

Smoke Meter Assembly:

Compressed Air - ON
Calibration ________
Positioning - 1 to 1 1/2 dia. to top of exhaust stack ________

Control Boom Assembly:

Manifold Pressure Line - Installed ________
Fuel Pressure Line - Installed ________
Fuel Feed Line - Installed ________
Oil Pressure Line - Installed ________
Temperature Thermocouple(s) - Installed ________
Fuel Solenoid Wiring - Connected ________

Dynamometers:

Drive Shaft - Connected ________
Drive Shaft Guard - Connected ________

Engine

Water Hoses - Connected ________
Exhaust System - Connected ________
Fuel Regulator - Correct Setting ________
Exhaust Sample Probes - Connected ________
Air Cleaner - Connected ________
Exhaust Restrictor - Connected ________
Inlet Air Restrictor - Connected ________
L.F.E. Connected ________

Console

All Potentiometers in OFF position ________
M. G. set - ON- 10 min. warm-up min. ________
Manometers calibrated ________
Rotation - correct for engine ________
Inertia - correct position (±) ________
Mode - Manual or tape ________
Strip chart recorder - ON ________

Power ON in M.G. Room ________
Primary Power - ON ________
Fuel Solenoid - ON ________
Temp. Recorder - ON ________
Wet Bulb thermo-filled and power ON ________
Fuel Conditioner- ON ________

Form HD-750-03

TP-750
Attachment No. 4.

Check List - Preparation of Test Engine for Return to Mfr.

Description		**Oper. Init.**
Disconnect:	Drive Shaft - Both Ends.	____________
	Engine Stand Lag Down Bolts.	____________
	L.F.E. - Diesel, only.	____________
	Accessory Stands.	____________
	Water Hoses from Coolant package.	____________
	Exhaust System at Exhaust manifold only.	____________
	All Temp. thermocouple wires from Control Boom Assembly.	____________
	All sample probe lines from engine only.	____________
	All fuel, oil, vacuum, manifold, pressure, and feed lines from Control Boom Assembly only.	____________
	Oil coolant hoses from Coolant package.	____________
Move Engine and Exhaust System		
	Diesel Engine(s) to Room 319.	____________
Disconnect,	Remove and put in proper place:	
	All Thermocouples, wires and fittings (if installed by E.P.A.)	____________
	Water Hoses	____________
	Drive Shaft	____________
	All fuel, oil, vacuum, manifold, pressure and feed lines and fittings.	____________
Drain:	Coolant complete; oil (if required).	____________
Re-Install:	All pipe plugs, cap plugs and other fittings removed by E.P.A.	____________
Disassemble: **Pack in Box:** **Strap to Skid:**	Exhaust System and all other engine parts and accessories received.	____________

Note: Check HD Rec. form to assure shipment is complete as received.

Form HD-750-04

Environmental Protection Agency
Office of Air & Water Programs
2565 Plymouth Road
Ann Arbor, Michigan 48105

SHIPPING ORDER

No.____________________

Date____________________

Ship To :	Charge To:
Address :	Address :
Attention:	Attention:

The following listed material/equipment/engine(s) now on consigment/loan to this facility is herewith returned per signature of your carrier (or, common carrier, if applicable.)

Quantity	Description	Ser. No.

The above items were received by____________________________________
(Signature)

on____________________________
(Date)

Form HD-750-05

EPA TEST PROCEDURE	Number TP-751	Page 1 of 7

SUBJECT

SMOKE MEASUREMENT TEST - HEAVY DUTY DIESEL ENGINE

Reference FEDERAL REGISTER NOVEMBER 15, 1972, PART 85 SUBPART I, SAE RECOMMENDED PRACTICE J255-1971	Data Form No. 751-01
Responsible Organization HEAVY DUTY TESTING/CERTIFICATION	Computer Program
Test Witness HD SUPERVISOR	Performance Interval EACH SMOKE TEST
Type of Test Report DATA VALIDATION - CERTIFICATION LABORATORY OPERATION - DATA FILE	Supersedes NONE
Report Distribution	Superseded by NONE

REMARKS/COMMENTS

ORIGINAL RELEASE APPROVALS

Office	Section	Signature	Date
Lab Oper.	Quality Assurance		
Test Oper.	Chief		
HD Testing	Supervisor		

REVISIONS

Change Letter	Description of Change	Approval	Date

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1.0 PURPOSE

To measure the opacity of the full smoke plume of a diesel engine during certain prescribed operating modes.

2.0 TEST ARTICLE DESCRIPTION

Applicable to new diesel heavy duty engines beginning with the 1974 model year. A heavy duty engine is defined as any engine which the engine manufacturer could reasonably expect to be used for motive power in a heavy duty vehicle.

3.0 REFERENCES

3.1 Federal Register, Vol. 37, November 15, 1972, Part 85 Subpart I, Paragraphs 85.802 thru 85.874-18.

3.2 "Diesel Engine Smoke Measurement", SAE Information Report, J255, June 1971.

4.0 REQUIRED EQUIPMENT/CONDITIONS

4.1 Engine dynamometer with adequate characteristics to perform the test cycle according to 85.874-11.

4.2 Smoke Meter - full flow opacity meeting specifications of 85.874-13.

4.3 Recorders for temperature, engine RPM, torque, smoke opacity, and throttle position.

4.4 Opacity filters for calibration of the smoke meter.

5.0 PRECAUTIONS

5.1 Do not mount the optical unit on the engine exhaust pipe rigidly. Engine vibration can shake the lamp filament which may register as "noise" on the recorder.

5.2 Shock mount the photo cell, solder all electrical connections, and strengthen mechanical parts.

5.3 Power Supply - Adjustable but constant voltage supply.

5.4 Air Supply - Bottled nitrogen or air or "house" air supply, properly filtered and dried may be used. The compressed air supply must be free of oil, water and dirt, any of which may obscure light and introduce error in the readings.

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5.0 PRECAUTIONS (continued)

5.5 Chart response characteristics can affect the reading obtained. The Federal Register (see 3.1) specifies recorder response for certification testing. This is especially important for transient smoke tests, and it should be established that the read out instrumentation used has the proper response for transient work. The optical system of the opacimeter is extremely fast and, with suitable recorders (light beam type or an oscilloscope) the smoke puffs from individual cylinders may be observed.

5.6 The open stack, a relatively critical location for the optical unit, and the need to calibrate on clean air are features not particularly well suited to laboratory engine testing. Hoods or funnels have been used successfully, but the particular exhaust gas disposal system must be considered when this smokemeter is used. The smoke ventilation system should not influence the shape of the exhaust plume. Exhaust noise and room ventilation also must be considered when testing indoors.

6.0 VISUAL INSPECTION

6.1 Inspect all electrical and air supply hook-ups for proper connection.

6.2 Check for burned out lamp in smokemeter.

6.3 Check all measuring devices for hook-up to correct read out devices.

6.4 Check ink supply and chart paper on all recorders.

7.0 TEST ARTICLE PREPARATION

7.1 Check operation of engine throttle control to insure WOT conformance with acceleration phases of smoke test.

7.2 Run engine to determine by experimentation the inertia and dynamometer load required to perform the acceleration phases of the smoke emission cycle.

7.3 The test is performed on a warm engine, preconditioned for 10 minutes at maximum rated horsepower.

8.0 TEST PROCEDURE

The test consists of a prescribed sequence of engine operating conditions on an engine dynamometer with continuous examination of the exhaust smoke opacity.

Test Sequence	Description	Data Output
101	Move proper equipment into test cell.	
102	Make all necessary electrical connections to record smoke opacity, engine speed, engine torque, and throttle position.	
103	Hook up air supply to smoke head and adjust. 1. Optical centerline 5 ±1" from pipe outlet. 2. Optical centerline at right angles to exhaust plume.	
104	Turn on power to control unit of smokemeter and allow minimum of 15 minutes for stabilization.	
105	Turn on power to recorder and allow sufficient time for specified warm up.	
106	Clean lenses in smoke head if necessary.	Instrument Log Entry
107	Turn on purge air to smoke head.	
108	Turn on chart recorder after checking paper supply and inking pens operation.	
109	Set zero and 100 percent opacity on smoke channel. Resolution to be within 1 percent opacity.	
110	Insert neutral density filters (nominal 10, 20 and 40 percent opacity) in light path on smokemeter (same side as light source). Verify that recorded values on the chart are within 1 percent of the filter value as determined by EPA.	
111	Contact instrument repairman and/or supervisor if desired calibration is not possible	Maintenance Log Entry

8.0 TEST PROCEDURE (Continued)

Test Sequence	Description	Data Output
112	Bring engine to rated speed and load. Adjust inlet and exhaust restriction per manufacturer's instructions (if required). Record the following:	HD-751-01
	BHP	BHP
	Fuel rate	lbs/min
	Inlet restriction	"H_2O
	Exhaust back pressure	"H_2O
	Ambient air temperature	°F
	Intake air temperature (within 68° to 86°)	°F
	Humidity and barometric pressure	"Hg
113	Lug engine to peak torque speed, record fuel rates and torque.	lbs/min Torque
114	Remove all dyno load and allow engine to run at maximum governed RPM. Record that RPM.	RPM
115	Reduce speed to low idle.	
116	Set zero and 100 percent on the smokemeter recorder with smoke head away from smoke plume. Insert neutral density filters (nominal 10, 20, and 40 percent). The recorded values must fall within ±1 percent of EPA established values.	
117	Recheck calibration of speed and torque for preconditioning.	
118	Remove all dyno load and bring engine to low idle. This represents start of first smoke cycle.	
119	Operate engine at low idle for 5 to 5.5 minutes.	
120	Center smokemeter head over exhaust plume during low idle.	
121	Increase recorder chart speed to a minimum of 6" per minute at end of low idle period.	Record Smoke, RPM Torque
122	Increase engine speed to 200 ±50 RPM above low idle within 3 seconds.	

8.0 TEST PROCEDURE (Continued)

Test Sequence	Description	Data Output
123	Accelerate engine at full throttle against dynamometer load selected earlier so that engine speed reaches 85 to 90 percent of rated speed within 5.0 ±1.5 seconds. Acceleration to be linear within ± 100 RPM.	
124	Move throttle rapidly to closed position and apply preselected load.	
125	Observe RPM drop. Apply full throttle so that engine speed reaches 60 percent of rated speed or peak torque speed (whichever is higher) within ± 50 RPM.	
126	Allow engine to accelerate for 10 ±2 seconds during which the engine speed must reach 95 percent of rated RPM.	
127	Stabilize engine at maximum rated HP under full throttle.	
128	Increase dyno load to lug engine to peak torque speed or 60 percent rated RPM (whichever is higher) within 35 ±5 seconds. Lug phase to be linear within ±100 RPM.	
129	Remove dyno load and reduce speed to low idle.	
	(Completion of One Test Cycle)	
130	Run two additional test cycles.	
131	Shut engine down; reduce recorder speed.	
132	Check smokemeter calibration. Repeat test if zero drift is greater than ±2 percent. Reset zero if drift is less than ±2 percent. Check 100 percent and insert neutral density filters Repeat test if recorded values deviate by more than ±2 percent of actual values.	

9.0 DATA INPUT

9.1 Data is recorded on Form No. HD-751-01.

10.0 DATA ANALYSIS

10.1 Verify that calibration of the smoke meter was properly performed.

10.2 Data validation verifies that all records are complete and within specified tolerances.

11.0 DATA OUTPUT

11.1 Recorded data and information are stored in the data files.

11.2 Final copies of data go to certification and to the manufacturer's representative.

12.0 ACCEPTANCE CRITERIA

12.1 Smokemeter calibrations must repeat within ±2 percent of zero and full scale.

12.2 Inlet air must be within 68-86°F.

12.3 Cycle must be accomplished within the speed, time and torque specifications for the engine as outlined in the Test Procedure.

13.0 QUALITY CONTROL PROVISIONS

13.1 Test must be repeated if specifications are not met.

13.2 Quality Assurance performs equipment and data audits periodically to determine adherence to proper procedure and instrument calibrations.

HEAVY DUTY DIESEL ENGINE TEST DATA SHEET

MANUF CODE | ENGINE IDENTIFICATION NO. | ENG. FAMILY | DATE BUILT | DISP | TEST POINT HOUR | E.O.H | TPE | DIA | CONF | NO CYL | MODEL YEAR | TEST YEAR | SMOKE TEST TYPE | SOURCE CODE | ROTATION | CRANKCASE | FUEL TYPE | INJ TYPE | CONT TYPE | ASPIRATION | GASEOUS TEST TYPE | CARD NO | DYNO NO | TEST NO

0,1

MANUF SPECS

IDLE RPM | EXH. SYS. BACK PRESS | AIR INLET REST | MAX TORQUE | RPM | (MHR) FUEL | MAX HP* | RPM | (MHR) FUEL | GOV'D SPEED | ENG. TEMP | INJECTOR TIMING | OIL | MAX CFM | HP²

0,2

MANUF SMOKE TEST: ACCEL | LUG | PEAK | BARO | TDB | TWB | ENG TEMP | ACCUM RUN HRS

MANUF GASEOUS TEST: BSHC | BSCO | BSNOX | BSHC+BSNOX | ENG TEMP | ACCUM RUN HRS

REQUESTOR: INIT | BR | JOB NO. | DATE

0,3

REQUESTOR COMMENTS

0,4

LABORATORY COMMENTS

0,5

EPA DATA

IDLE RPM | EXH.SYS. BACK PRESS | AIR INLET REST | MAX # TORQUE | RPM | (MHR) FUEL | MAX # HP | RPM | (MHR) FUEL | GOV'D SPEED | ENG. TEMP | FUEL CO | OPCODE | AF(1) | AF(2)

GASEOUS TRAIN & TEST NO

TEST COMPLETED: TIME | DATE

0,6

K-400 SMOKE TEST: ACCEL | LUG | PEAK | BARO | TDB | TWB | ENG TEMP | ACCUM RUN HRS | OPER ENG | INST | TRAIN & TEST NO

K-400 GASEOUS TEST: BSHC | BSCO | BSNOX | BSHC+BSNOX | ENG TEMP | ACCUM RUN HRS | OPER ENG | INST

0,7

CYCLE

ACCELERATION: 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15

LUGGING: 1 | 2 | 3 | 4 | 5

1 — 0,8

2 — 0,9

3 — 1,0

METER DEFLECTIONS

MODE

R | HC | R | CO | R | CO2 | R | NO | R | NOX | R | O2 | RPM | TORQUE | BARO | TDB | TWB

FLOWMETER (1): T1 | DP1 | ΔP

FLOWMETER (2): T1 | DP1 | ΔP

(LBS) FUEL

1 — 1,1

2 — 1,2

3 — 1,3

4 — 1,4

5 — 1,5

6 — 1,6

7 — 1,7

8 — 1,8

9 — 1,9

10 — 2,0

11 — 2,1

12 — 2,2

13 — 2,3

Form No. HD-751-01

CARD CODES

CARD 1

MANUF. CODE (COL. 1-3)

CODE	EQUIVALENCE
31	FORD MOTOR CO.
46	G.M. (G.M.C.)
47	G.M. (DETROIT DIESEL)
95	A.M. GENERAL
200	MERCEDES-BENZ
250	HINC
270	IHC
290	ISUZU
380	NISSAN
490	MITSUBISHI
600	AB VOLVO
720	WINEBAGO
725	ALLIS-CHALMERS
730	CATERPILLAR
740	CUMMINS
750	HERCULES
760	MACK
770	PERKINS
780	SCANIA-VABIS
800	TELEDYNE CONT.
810	CASE
820	DIAMOND REO

ENGINE ID (COL. 4-19)- LEFT JUSTIFIED

ENGINE FAMILY (COL.20-31)- LEFT JUSTIFIED

DATE BUILT (COL.32-37)- MO-DAY-YR

EXHAUST PIPE DIAMETER - MEASURED IN INCHES (COL.47-49)

MODEL YEAR (COL.54-55)- MODEL YEAR OF ENGINE

TEST YEAR (COL.56-57)- TEST YEAR PROCEDURE

SMOKE TEST TYPE (COL.58-59)

CODE	EQUIVALENCE
0	VOID
1	CERTIFICATION
2	DURABILITY
3	CORR. (CERT)
4	SURVEILLANCE
5	EXPERIMENTAL
6	FIELD SURV.
7	PARTICULATES
8	OTHER
9	CVS CORRELATION
10	RESEARCH
11	CORR. (LAB)
12	
13	
14	

SOURCE CODE (COL. 60-61)

CODE	EQUIVALENCE
1	MANUFACTURER
14	DEALER
15	EPA
16	GSA
17	MILITARY
18	PRIVATE OWNER
19	OTHER

ROTATION (COL. 62)

CODE	EQUIVALENCE
1	CLOCKWISE
2	COUNTERCLOCKWISE
3	N/A

CRANKCASE (COL. 63)

CODE	EQUIVALENCE
1	CLOSED
2	OTHER

FUEL TYPE (COL. 64)

CODE	EQUIVALENCE
1	TYPE 1-D
2	TYPE 2-D

INJ. TYPE (COL. 65)

CODE	EQUIVALENCE
1	DIRECT
2	INDIRECT
3	OTHER

EXHAUST EMIS. CONTROL SYS (COL. 66)

CODE	EQUIVALENCE
1	ANEROID
2	
3	N/A

AIR ASPIRATION (COL. 67)

CODE	EQUIVALENCE
1	NATURAL
2	TURBOCHARGED
3	SUPERCHARGED
4	TURBOSUPERCHARGED
5	TURBOSUPERCHARGED AFTERCOOLED
6	OTHER

GASEOUS TEST TYPE (COL. 68-69)
(SAME AS SMOKE TEST TYPE CODING)

CARD 2 AND CARD 6

GOVERNED SPD. (COL.38-41)- NO-LOAD GOVERNED SPEED (HIGH IDLE RPM)

CARD 6

FUELCO (COL.45) - INPUT "M" MEANS FUEL IS MEASURED IN LBS/MIN
INPUT "H" MEANS FUEL IS MEASURED IN LBS/HR

OPCODE (COL.46) - OPERATION CODE
0 = K-400 ONLY (FIRST 7 CARDS ARE NEEDED)
1 = SMOKE TEST ONLY (FIRST 10 CARDS)
2 = GASEOUS TEST ONLY (CARDS 1-7 AND 11-23)
3 = ALL TESTS (ALL 23 CARDS)

AF(1) (COL.47) - FIRST LAMINAR FLOW METER UNIT NO.

AF(2) (COL.48) - SECOND LAMINAR FLOW METER UNIT NO.

EPA TEST PROCEDURE	Number TP-752	Page 1 of 6

SUBJECT

MEASUREMENT OF INTAKE AIR FLOW OF DIESEL ENGINE

Reference SAE RECOMMENDED PRACTICE - J244	Data Form No. HD-751-01
Responsible Organization TEST OPERATIONS - HEAVY DUTY	Computer Program
Test Witness SUPERVISOR - HEAVY DUTY	Performance Interval EACH TEST
Type of Test Report	Supersedes NEW
Report Distribution	Superseded by

REMARKS/COMMENTS

ORIGINAL RELEASE APPROVALS

Office	Section	Signature	Date
Lab. Oper.	Quality Assurance		
Test Oper.	Chief		
HD Testing	Supervisor		
Certification	Heavy Duty		

REVISIONS

Change Letter	Description of Change	Approval	Date

REVISIONS:	MEASUREMENT OF INTAKE AIR FLOW OF DIESEL ENGINES **TEST PROCEDURE**	PROCEDURE NO. TP-752 PAGE 2 OF 6

1.0 PURPOSE

To determine the air flow of the diesel engine in pounds per minute or kilograms per minute during the gaseous emissions measurement procedures.

2.0 TEST ARTICLE DESCRIPTION

Diesel engine mounted on dynamometer test stand.

3.0 REFERENCES

3.1 SAE recommended practices J-244 - measurement of intake air or exhaust gas flow of diesel engines.

3.2 Instruction Manual - the Meriam Laminar Flow Meter Model 50 MC2.

4.0 REQUIRED EQUIPMENT/CONDTIONS

4.1 Filter - as required by flowmeter.

4.2 Laminar Flow Meter - Model No.

50 MC2 - 4F
50 MC2 - 6SF
50 MC2 - 8F

as required by engine flow.

4.3 Restriction valve to control engine inlet air pressure.

4.4 Chamber connection to engine which allows use of engine air filter with tight seal to engine intake air assembly.

4.5 Pressure Sensor - Manometer for measurement of inlet air pressure.

4.6 Temperature sensor for measurement of inlet air temperature.

4.7 Incline manometer for manual reading of ΔP across flow element. Transducers for measuring ΔP for computer input.

5.0 PRECAUTIONS

5.1 For minimum pulsation effect on the inclined manometer for measuring ΔP the lines should be made of soft tubing, equal length, and equal diameter, and isolated from other lines when reading ΔP.

5.2 Filters must be replaced as recommended by meter manufacturers or when the total pressure loss through the intake system exceeds the test requirements.

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5.3 Laminar flow elements should not be disassembled for cleaning. Periodic cleaning and calibration by the manufacturer is recommended.

5.4 The engine must be examined and modified as required to assure that all measured air and no unmeasured air enters the combustion chamber.

5.5 The differential pressure tubing must be clear of all liquids and all connections must be absolutely leak free. If the manometer water is accidentally sucked into the lines, they must be thoroughly cleaned.

5.6 It is recommended that manometer reading of ΔP in the lower 10 percent of scale be avoided.

6.0 VISUAL INSPECTION

6.1 Check installation for possible areas of leakage - assure tight connection at intersecting parts.

6.2 Check air filter for dust accumulation.

6.3 Check for proper connection of temperature and pressure devices.

7.0 TEST ARTICLE PREPARATION

Refer to procedure for receipt, build up and installation of diesel test engines.

8.0 TEST PROCEUDRE

The proper air flow element sized for the particular diesel engine being tested is connected to the engine.

Test Sequence	Test Description	Data Output
101	Test for air-tightness of the air metering system - care must be exercised to prevent unmetered air from entering the engine. Even small leaks result in substantial errors when the flow rates are in the range of 50-500 lb/hr.	-
	o Cap both ends of the assembly and pressurize the system to approximately 12 inches H_2O air pressure. Shut off the air supply, let the pressure drop to 6 inches H_2O, and record the time to drop to this pressure.	Time (seconds)
	o Calculate the leakage with the following formula: $$m_L = \frac{0.00038\ \Delta P\ Vol}{TI}$$ where m_L = lb/hr Vol = total volume, inches^3 P = pressure differential, inches H_2O TI = time for pressure to change	
	o Acceptable leakage rate for this procedure is 0.5 percent of lowest flow rate to be measured during the test.	
	o If vacuum check is desired simply evacuate the assembly to a -12 inches H_2O. Use same formula for calculations.	
102	Level the inclined manometer.	
103	Zero the meniscus. The meniscus may be zeroed during running by venting to atmosphere.	

REVISIONS:	MEASUREMENT OF INTAKE AIR FLOW OF DIESEL ENGINES **TEST PROCEDURE**	**PROCEDURE NO.** TP-752 **PAGE** 5 **OF** 6

Test Sequence	Test Description	Data Output
104	The pressure differential is measured directly using an inclined manometer graduated to permit accuracy of 0.5 percent of the smallest ΔP to be measured. The ΔP may be read in inches of water or directly in flow units.	
105	Read ΔP when engine has reached equilibrium and record.	ΔP in H_2O
106	At same time as ΔP is measured record temperature, barometer, humidity, fuel flow rates, engine speed, and torque, air system pressures and temperature.	Data Sheet Entry
107	Calculate mass flow at each engine operation using the calibration curve supplied by the manufacturer.	

9.0 DATA INPUT

Record all ambient conditions and required flow measurement data on heavy duty diesel engine test data sheet. (HD-751-01)

10.0 DATA ANALYSIS

10.1 Check for obvious discrepancies in data entries from one mode to the next.

10.2 Verify all ambient conditions are within specifications (68-86°F and 28.5-31.0 inches Hg.)

10.3 Compare flow rates with manufacturer's data and previous runs on engine.

11.0 DATA OUTPUT

11.1 The data is combined with other test data to calculate the emissions and stored in data files.

11.2 Data on certified engines sent to Certification.

12.0 ACCEPTANCE CRITERIA

12.1 Acceptance criteria are specified in test procedure.

13.0 QUALITY PROVISIONS

13.1 Leak check of air measurement system is performed and any leaks found are corrected.

13.2 Pressure transducer checked each test against incline manometer before and after 13 mode cycle. Change in transducer calibration may invalidate test or required manual reduction of data if inclined manometer is used.

EPA TEST PROCEDURE	Number TP-753	Page 1 of 10

SUBJECT DIESEL ENGINE EMISSION MEASUREMENT PROCEDURE CARBON MONOXIDE (CO), NITRIC OXIDE (NO) AND OXYGEN (O_2)	
Reference FEDERAL REGISTER, VOLUME 37, NOVEMBER 15, 1972	Data Form No. HD-751-01
Responsible Organization TEST OPERATIONS - HEAVY DUTY	Computer Program
Test Witness SUPERVISOR - HEAVY DUTY TESTING	Performance Interval EACH TEST
Type of Test Report DATA SHEET, PUNCH CARD - COMPUTER PRINT OUT	Supersedes NEW
Report Distribution DATA VALIDATION - DATA FILE - CERTIFICATION	Superseded by

REMARKS/COMMENTS

ORIGINAL RELEASE APPROVALS

Office	Section	Signature	Date
Lab. Oper.	Quality Assurance		
Test Oper.	Chief		
HD Testing	Supervisor		

REVISIONS

Change Letter	Description of Change	Approval	Date

1.0 PURPOSE

To determine the brake specific mass emissions of carbon monoxide (CO) and nitrogen oxides (NO_x) from heavy duty diesel engines when operated through the prescribed cycle which spans the typical operating range of diesel engines.

2.0 TEST ARTICLE DESCRIPTION

Heavy duty diesel engine - any compression ignition internal combustion engine which the engine manufacturer could reasonably expect to be used for motive power in a heavy duty vehicle.

3.0 REFERENCES

3.1 Federal Register, Title 40 Part 85, Paragraph 85.974-1 thru 85.974-18 November 15, 1972 and subsequent revisions.

3.2 SAE Recommended Pratices J177, Measurement of Carbon Dioxide, Carbon Monoxide and Oxides of Nitrogen in Diesel Exhaust, March 1971.

3.3 SAE Recommended Practices J1003 - Diesel Engine Emission Measurement Procedure - March 1973.

4.0 REQUIRED EQUIPMENT/CONDITIONS

4.1 Instrumentation shall be provided to measure the following engine operating data:

(a) Engine speed: RPM
(b) Torque: Ft-lbs
(c) Mass Fuel Consumption: lb/min (Kg/min)
  o Flotron or
  o Cox Instrument (dead weight)
(d) Observed barometer: inches Hg (Pa)
  o Bell and Howell Digital Model 4-461-002
(e) Water vapor pressure: inches Hg (Pa)
  o Wet Bulb and Dry Bulb Hygrometer
(f) Intake air restriction: in. water
(g) Exhaust back pressure: in Hg (Pa)
(h) Intake air temperature °F (k)
(i) Fuel temperature at pump inlet °F (k)

4.2 Recorders as required for above listed instruments and for the analytical instruments.

4.3 Digital volt meter for measuring instrument output.

4.4 General Electric Direct Current Dynamometer, 600 hp, Model 426408AD equipped with Unisystems, Inc. controls and cooling system.

4.5 Analytical console for continuous and simultaneous analysis of CO, NO and O_2. The console will be equipped with appropriate flowmeters, condenser valves, filters and pumps as prescribed in SAE J177 and EPA sample console design No.________. The console is to consist of the following instruments.

(a) MSA-NDIR Model 200 FR for measurement of CO with the following ranges 2.5 percent, 1,000 PPM, 5,000 PPM.

(b) MSA-NDIR Model 202 for measurement of NO with the following ranges 1,500 PPM, 6,000 PPM.

(c) Beckman Model 778 Polorgraphic Oxygen Analyzer 0.5 percent and 0-25 percent.

4.6 Calibration (span gases) for routine check of the instrument response.

5.0 PRECAUTIONS

5.1 Allow 2 hour minimum warm-up of analyzers.

5.2 The chemical kinetics of combustion reactions highly favor the formation of NO over NO_2. The NO formed does convert to NO_2 in the presence of oxygen, with the degree of conversion being related to time and the O_2 concentration in the sample. In order to decrease this conversion sample, transport time to the analyzer should be kept to a minimum. In addition parallel check with a CHEMI instrument equipped with a converter can be used to determine the percent conversion of NO to NO_2.

5.3 Nitric oxide calibration gases used with NDIR-NO instrument should be analyzed for NO and NO_2 separately. NO_2 contamination should be kept at a minimum (less than 10 PPM.)

5.4 Regulators used for NO gases should be of stainless steel and teflon construction. In-board leakage of air (O_2) can cause problems of conversion to NO_2 in the regulator. Regulators and associated plumbing must be carefully leak checked and well purged when calibrating.

5.5 Carbon Monoxide gas mixtures may change with age, especially the lower concentration. The span gas should be checked each time a curve check is performed.

5.6 Exhaust from diesel engines contains a greater amount of particulate than gasoline engines consequently the frequent cleaning of sample lines is recommended. Use of a prefilter near the sample inlet can reduce the contamination problem, if the prefilter is changed after each test.

6.0 VISUAL INSPECTION

6.1 Check all connections to the analytical console to insure secure connection of sample line, gas mixtures and electrical lines.

6.2 Check all valve positions before start-up for proper position.

6.3 Check all electrical switches for proper position before start-up instrument checks.

6.4 Insure cooling and fuel systems are operational.

7.0 TEST ARTICLE PREPARATION

7.1 The governor and fuel system should be adjusted to provide engine performance at the levels specified by the engine manufacturer for maximum rated horsepower and maximum rated torque.

7.2 Install instrumentation and sample probes as required.

7.3 Conduct the test on a warm engine. Start the engine, warm it up by running it at rated speed and maximum horsepower for 10 minutes or until all temperatures and pressures have reached equilibrium.

7.4 Determine the maximum torque at rated speed and intermediate speed to calculate the torque values for the specified test modes. Intermediate speed is 60 percent of rated speed or 1800 RPM, whichever is higher.

7.5 Install and check air flow measurement system according to procedure No. TP-752.

8.0 TEST PROCEDURE

The diesel emissions are measured at steady-state conditions during the prescribed 13 mode cycle.

Test Sequence	Test Description	Data Output
	Pretest System Preparation	
101	o Verify appropriate zero and span gases of appropriate concentrations and quantities are available.	
102	o Warm up instrumentation.	
103	o Check sample probes and lines and clean/replace as required.	
104	o Verify appropriate probe length and location.	
105	o Leak check entire sample system (before and after test.)	
106	o Clean/replace filter/filter elements as necessary.	
107	o Drain water from sample line traps in refrigerated bath.	
108	o Install driers and condition as required.	
109	o Load recorder and verify functional operation.	
110	o Complete functional check out of instrumentation system.	
111	o Adjust zero gas flow rate and zero analyzer and readout device.	
112	o Adjust span gas flow rate, span analyzer and readout device (use calibration curve if required.)	
113	o If gain has changed by more than 3 percent locate and correct problem.	Maintenance Log Entry
114	Adjust sample flow rates as applicable.	

8.0 TEST PROCEDURE (Continued)

Test Sequence	Test Description	Data Output
115	o Recheck zero and span and check agreement between primary output device (computer) and strip chart.	

Diesel Gaseous Emission Cycle

116 o The following 13 mode cycle shall be followed in dynamometer operation of heavy duty diesel engines:

Mode No.	Engine Speed	Percent Load
1	Low idle	0
2	Intermediate	2
3	do	25
4	do	50
5	do	75
6	do	100
7	Low idle	0
8	Rated	100
9	do	75
10	do	50
11	do	25
12	do	2
13	Low Idle	0

117 During each mode the specified speed shall be held to within 50 RPM and the specified torque shall be held to within 2 percent of the maximum torque at the test speed. For example, the torque for mode 4 shall between 48 and 52 percent of the maximum torque measured at the intermediate speed.

118 During the 13 mode cycle the following should be checked and recorded during the last 5 minutes of each mode.

Test Description	Data Output
o Engine speed at required tolerance for each mode	RPM
o Torque at required tolerance for each mode	Torque
o Engine operated for required time in each mode	Mode Time
o Fuel within specified tolerance	Fuel Flow (Lbs) T°F

8.0 TEST PROCEDURE (Continued)

Test Sequence	Test Description	Data Output
	o Barometric pressure is within limits	Bar. In. Hg.
	o Inlet air and restriction within specified tolerances	Air flow T^oF Inlet Restriction
	o Exhaust back pressure within tolerance	Exhaust Pressure
119	Fuel flow during idle or 2 percent load condition may be determined just prior to or immediately following the dynamometer sequence, if longer times are required for accurate measurement.	
120	Speed and load reuirements must be met during the last minute of each mode.	
121	Operate the engine for 10 minutes in each mode, completing engine speed and load changes in the first minute. If a delay of more than 10 minutes occurs between the end of one mode and the start of the next mode discontinue the sequence and repeat the test from mode no. 1.	
	Analytical Procedure	
122	Record the response of the analyzers on a strip chart recorder and/or computer for the full 10 minutes with exhaust gas flowing through the analyzers at least during the last 5 minutes. Mode times are determined from the chart intervals or by signal to computer of start and end of each mode.	Data Process Entry
123	Check and reset the zero and span settings of the emission analyzers as required, but at least at the end of the test. If a change of over 2 percent of full scale response is observed, make necessary adjustments to the analyzers and repeat all test modes since the last zero and span check.	
124	Read and record the following additional information (a) Test number (b) Date and time of day (c) Instrument operator (d) Engine operator	

8.0 TEST PROCEDURE (Continued)

Test Sequence	Test Description	Data Output
	(e) Engine identification numbers--date of manufacture--number of hours of operation accumulated on engine--engine family--exhaust pipe diameter--fuel injector type--low idle r.p.m., governed speed, maximum power and torque speeds--maximum horsepower and torque--fuel consumption at maximum power and torque--air aspiration system--exhaust system back pressure--air inlet restriction.	
	(f) All pertinent instrument information such as tuning--gain--serial numbers--detector numbers--range.	
	(g) Recorder chart. Identify zero traces--calibration or span traces--emission concentration traces for each test mode--start and finish of each test.	
	(h) Ambient temperature in dynamometer testing room.	
125	Backflush condensate trap and replace filters as required.	
126	Chart reading - locate the last 60 seconds of each mode and determine the average chart reading for CO, NO, and O_2 over the 1 minute period	Percent Deflection
	Concentrations may be determined for each mode using the corresponding calibration data.	

9.0 DATA INPUT

All data is recorded and the computer process Form No. HD 751-01 is submitted to Data Validation for review.

If manual reduction is required refer to FR 85.97418 for applicable formulas for calculation of brake-specific emissions.

10.0 DATA ANALYSIS

10.1 Check all entries for spurious values and out of tolerance reading for each mode.

10.2 Compare brake-specific emissions with Federal standards and previous engine data if available.

11.0 DATA OUTPUT

Test data is entered into data file and reported to certification and test operations.

12.0 ACCEPTANCE CRITERIA

Specifications and tolerances are identified in test procedure sequence no. 113, 117, 120, 122. In addition inlet air temperature must be between 68-86°F and barometric pressure between 28.5 and 31.0 inches Hg.

13.0 QUALITY PROVISIONS

13.1 Any time/speed/torque tolerance not met invalidates the test and the complete 13 mode test must be rerun.

13.2 Out of tolerance temperature of inlet air and fuel, and barometric pressure will invalidate test.

13.3 If the test was void, a failure report (test condition report Form No. HD-709-01) shall accompany the test data sheet and the type of failure should be coded in the space provided.

13.4 Final test disposition shall be indicated on the data sheet.

13.5 Instrument calibration curves shall be checked monthly according to procedure TP-203.

13.6 Periodic audits are made of each test cell to assure proper calibration intervals have been followed for all instruments and equipment.

13.7 Dynamometer torque and engine RPM are calibrated monthly. Meter/recorder/computer input should be aligned monthly and checked daily.

13.8 Carbon Dioxide may be measured (optional), and a comparison of fuel flow vs total carbon in the exhaust could be used to better assure test reliability.

EPA TEST PROCEDURE

Number TP-754	Page 1 of 8

SUBJECT DIESEL ENGINE EMISSION MEASUREMENT PROCEDURE HYDROCARBONS (HC)	
Reference "CONTINUOUS HYDROCARBON ANALYSIS OF DIESEL EMISSION," SAE J215	Data Form No. HD-751-01
Responsible Organization TEST OPERATION - HEAVY DUTY	Computer Program
Test Witness SUPERVISOR - HEAVY DUTY TESTING	Performance Interval EACH TEST
Type of Test Report DATA PROCESS PRINT OUT	Supersedes NEW
Report Distribution CERTIFICATION, LAB OPERATIONS, SUPERVISION	Superseded by

REMARKS/COMMENTS

ORIGINAL RELEASE APPROVALS

Office	Section	Signature	Date
Lab. Oper.	Quality Assurance		
Lab. Oper.	Chief		
Testing Oper.	Supervisor HD		
Certification	Chief		

REVISIONS

Change Letter	Description of Change	Approval	Date

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1.0 PURPOSE

This procedure provides for the continuous measurement of the hydrocarbon concentration in diesel exhaust determined as brake-specific emissions.

2.0 TEST ARTICLE DESCRIPTION

Any compression ignition internal combustion engine which the manufacturer could reasonably expect to be used for motive power in a heavy duty vehicle.

3.0 REFERENCES

3.1 Federal Register, Title 40 Volume 37, dated November 15, 1972 and subsequent revisions paragraphs 85.874-13 thru 85.874-18.

3.2 "Continuous Hydrocarbon Analysis of Diesel Emissions" SAE Recommended Practice J215, November 1970.

3.3 Operating Manual - Beckman Model 402.

4.0 REQUIRED EQUIPMENT/CONDITIONS

4.1 Heated flame ionization (HFID) Hydrocarbon analyzer. Beckman Model 402 with the following ranges:

4.2 Heated stainless steel sample line to maintain exhaust temperature at $375^{o}F \pm 5^{o}$ from engine to instrument.

4.3 Heated and insulated sample pump and prefilter located near engine exhaust sample probe.

4.4 Recorder for HFID output.

4.5 Required temperature measurement devices, thermocouples, meters, recorders.

4.6 Calibration gases - propane in air for required ranges.

4.7 Zero gas - Prepurified air having a hydrocarbon concentration measured as methane of less 0.1 PPMC.

4.8 Fuel gas - 60 percent Helium 40 percent Hydrogen.

5.0 PRECAUTIONS

5.1 Care must be taken to heat the sample line uniformly, as hot or cold spots in the line could cause erroneous readings.

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5.0 PRECAUTIONS (Continued)

5.2 The oxygen response must be determined for each instrument. If the correction is determined to be greater than ±2 percent the observed PPMC must be corrected by multiplying by the correction factor.

5.3 All air zero and fuel gases should be analyzed for hydrocarbon content before being released for on-line use.

5.4 Instrument operating parameters such as sample, burner air and fuel flows; detector temperatures, and detector pressure should be carefully controlled to the same set points from test to test and when zeroing and spanning instrument.

6.0 VISUAL INSPECTION

6.1 Check all fitting, gauges, valves, regulators, line etc. for proper connection and operations prior to span check.

7.0 TEST ARTICLE PREPARATION

See Procedure No. TP-753 Section 7.0.

8.0 TEST PROCEDURE

The hydrocarbons in diesel exhaust are measured concurrently with the CO and NO during the 13 mode diesel cycle as described in Procedure No. TP-753.

Test Sequence	Test Description	Data Output
101	Follow the HFID instrument manufacturer's specifications for startup and operating procedures. If operating parameters determined by experimentation or by steps, 102, 103 give better results than those of the manufacturer, special instructions for setting parameters should be noted on the instrument.	
102	Optimize Detector Response	
	(a) Set burner fuel and air settings as prescribed by the manufacturer. Ignite the burner.	
	(b) Set the oven temperature at 160 ±10° C (320 ±18° F.) Allow at least 1/2 hour after startup for system to reach equilibrium.	
	(c) Determine optimum burner fuel flow for maximum response. Introduce a constant continuous concentration of propane in N_2. Use about 500 ppmc hydrocarbon concentration. Vary burner fuel flow and determine peak response. Select an operating flow that gives maximum response and the least variation in response with minor flow variations. Use best judgment in selecting optimum fuel flow.	Instrument Log Entry
	(d) Determine optimum air flow. Set burner fuel flow as determined in paragraph (c) and vary air flow. Although less critical than burner fuel flow, nonoptimized conditions may reduce quantitative accuracy. If air flow is too low, response is low. High air flow may result in increased noise. Select desired air flow and, if it is significantly different than that used in paragraph (c) repeat step (c).	
	(e) Measure optimum flows accurately and record.	

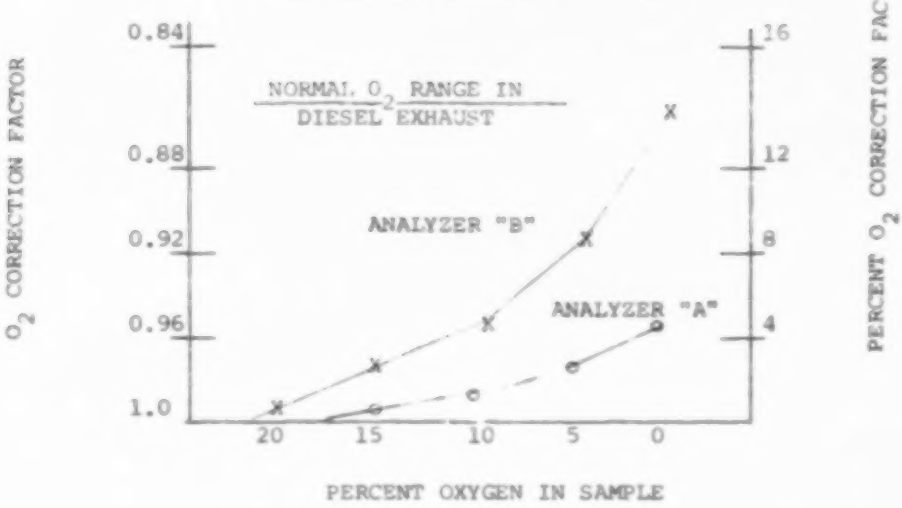
8.0 TEST PROCEDURE (Continued)

Test Sequence	Test Description	Data Output
103	Oxygen Response Curve of HFID	
	Excess air in diesel exhaust can cause variations in detector response. This effect is due to the oxygen concentration in the sample and its magnitude must be determined and minimized.	
	(a) Ignite burner and set flows as determined in 102. Set oven temperature and allow at least 1/2 hour after heat up for system to reach equilibrium.	
	(b) Introduce air zero gas and zero the analyzer.	
	(c) Determine oxygen response by introducing propane calibration gases in the following carrier gases: 100 percent N_2, 15 percent O_2, 100 percent air.	
	The concentration level of the propane should equal the expected upper HC level, or about 1,000 ppmc. The HC concentration and O_2 concentration should be known within ±2 percent of true value.	
	Recheck zero after each calibration gas is used. If zero has changed by more than 2 percent of the measure response value, rezero and repeat the test.	Instrument Log Entry
	(d) Using propane in air as the baseline for zero O_2 correction, plot a curve of oxygen correction versus the percent of oxygen in the sample (see Figure 1.) If the O_2 correction is less than ±2 percent at the oxygen levels present in the exhaust sample, no O_2 correction need be applied to the observed HC concentrations. If the correction is greater than ±2 percent, apply an O_2 correction to all measured values as follows:	Plot Curve
	Corrected ppmc = (observed ppmc) x (O_2 correction.)	

8.0 TEST PROCEDURE (Continued)

Test Sequence	Test Description	Data Output
	(e) Check effect of O_2 using a propane concentration typical of the expected lower HC level that will be encountered during the engine tests, or about 100 ppmc. If significantly different from the 1,000 ppmc data in 102 paragraph (d), establish curve and apply the O_2 correction on a prorated basis as a function of the measured concentration.	Instrument Log Entry

OXYGEN RESPONSE CURVE OF HFID



Analyzer A - Oxygen correction not needed
Analyzer B - Oxygen correction needed*

$$*\%O_2 \text{ Correction} = \frac{(\text{HC response in } N_2) - (\text{HC response in air})}{\text{HC response in air}}$$

Fig. 1 - FID OXYGEN INTERFERENCE

Test Sequence	Test Description	Data Output
104	Pretest system preparation - refer to Test procedure No. TP-753 test sequences 101 thru 115.	
105	Verify operating system temperature stability	

8.0 TEST PROCEDURE (Continued)

Test Sequence	Test Description	Data Output
106	Analyze Diesel exhaust hydrocarbons at steady state condition according to the test sequence 122 and 123 in Test procedure No. TP-753.	Data Process Entry

9.0 DATA INPUT

9.1 Data Processing Form (HD-751-01) is sent to data service after data validation has been performed according to Test procedure No. TP-850.

9.2 All test records are filed by test number and manufacturer.

10.0 DATA ANALYSIS

See Test procedure No. TP-753.

11.0 DATA OUTPUT

Test data is entered into data file and reported to certification or test requester.

12.0 ACCEPTANCE CRITERIA

12.1 HFID instrument parameters and sample line temperatures must meet tolerances during entire test.

12.2 If oxygen response exceeds 2 percent at exhaust O_2 level, data must be corrected using correction factor determined in test sequence 103.

13.0 QUALITY PROVISIONS

13.1 HFID instrument span and zero are checked before, during, and after test. Significant deviation requires rerun of test cycle from last acceptable span and zero check.

13.2 Detector and sample lines are heated to prevent hydrocarbon condensatio and hangup, and are held within specified tolerance, to reduce test to test variability.

13.3 Sample flow rates adjusted for maximum response and minimum transport time.

13.4 Oxygen response checked monthly.

13.5 Curve check performed monthly.

13.6 QA audit of maintenance log and instrument performance.

EPA TEST PROCEDURE	Number TP-755	Page 1 of 7

SUBJECT

FUEL FLOW MEASUREMENT - FLO-TRON LMF METER

Reference INSTRUMENT MANUAL MODEL 10 D	Data Form No. HD-751-01
Responsible Organization HEAVY DUTY TESTING	Computer Program
Test Witness SUPERVISOR	Performance Interval EACH TEST
Type of Test Report DATA PROCESS FORM NO.	Supersedes NEW
Report Distribution CERTIFICATION, MANUFACTURER REPRESENTATIVE	Superseded by

REMARKS/COMMENTS

ORIGINAL RELEASE APPROVALS

Office	Section	Signature	Date
Admin.	Quality Assurance		
Lab. Oper.	Chief		
HD Testing	Supervisor		

REVISIONS

Change Letter	Description of Change	Approval	Date

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REVISIONS:	FUEL FLOW MEASUREMENT - FLO-TRON LMF METER **TEST PROCEDURE**	**PROCEDURE NO.** TP-755 **PAGE** 2 **OF** 7

1.0 PURPOSE

This procedure describes the use of the Flo-Tron LMF for measurement of fuel flow during an emission test.

2.0 TEST ARTICLE DESCRIPTION

This flow measuring device is designed for use with diesel fuel and gasoline.

2.1 The model 10 D Electronic Mass Flow Transmitter is based on the hydraulic Wheatstone Bridge principle. The meter measures true mass flow rate and has an electrical output. The electrical output signal is obtained from a pair of integrally mounted differential pressure transmitters. These transmitters are incorporated with a Flo-Tron Signal Conditioner and Mass Flow Indicator.

2.2 Model 45 Recirculating Tank. The Flo-Tron Recirculating Tank is a device for use with an instantaneous readout flowmeter to measure net fuel consumption of a diesel engine. The unit is equipped with a float operated valve to maintain a constant level in the tank as well as baffles to remove entrained air and vapors from the engine return flow. A pressure regulator, with gage, is also furnished to control the inlet pressure to the float valve.

3.0 REFERENCES

3.1 Flo-Tron LMF meter data sheet and operation instructions for Model 10 D.

4.0 REQUIRED EQUIPMENT/CONDITIONS

4.1 115 Volts 4.2 Amps.

4.2 Flo-Tron Model 45 Recirculating Tank.

4.3 Flo-Tron Model 29-16 Signal Conditioner.

4.4 Mass Flow Indicator, Flo-Tron Model 24B.

5.0 PRECAUTIONS

5.1 LOCATION. To obtain optimum performance, the flowmeter should be located in a clean area which is free of vibration. Enough space should be left around the unit for access to the vent fittings and the span and zero adjustments. Space should be left for removal of the electrical housing covers.

The baseplate of the flowmeter should be in a horizontal position to preserve the self-venting feature.

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5.2 FLUID CONNECTIONS. Before making the fluid connections, remove the protective closures and drain any preserving oil from the meter. It is recommended that a good grade of pipe sealer be used on all fluid connections. Loctite Hydraulic Sealant, used with Locquic Primer has been found to work exceptionally well. Care should be exercised to keep this material from getting into the meter.

5.3 A 25 micron filter should be located directly upstream from the flowmeter inlet. This filter should be of sufficient capacity to insure that its pressure drop does not allow the meter inlet pressure to fall below 15 p.s.i. Connecting lines to and from the meter should be clean and free of loose material.

5.4 MOTOR WIRING. The flowmeter has a pump that is driven by an electric motor. The standard electric motor operates on 115 VAC, 60 Hz single phase and is thermally overload protected. Check motor nameplate for electrical characteristics of special units. The motor should be wired through a switch per the applicable electrical codes.

5.5 If the system is to be used in a "noisy" electrical environment i.e., near a spark ignition engine, it is desirable to use shielded connecting cables with the shields grounded at one location.

5.6 MOUNTING. It is important that the recirculating tank be mounted properly. The unit is designed to sense small changes in fuel level and therefore becomes somewhat sensitive to shock and vibration. It is recommended that the recirculating tank be mounted securely to a horizontal surface by the feet provided. This mounting surface should be rigid and free of shock and vibration. The cover should be left on the tank at all times to prevent the entrance of foreign matter.

5.7 FLUID TEMPERATURE AND PRESSURE. The fluid temperature and pressure should be within the limits specified 90-110°F and 15 p.s.i.g. It is possible, when operating with low vapor pressure fuels, that combinations of high temperature and low pressure may cause the liquid to flash into vapor. This can cause erratic and erroneous flow measurements. Therefore, with certain fuels it may be necessary to increase the system pressure or decrease the temperature to prevent flashing.

5.8 The indicators are factory set for desired input and output ranges. This provides maximum precision and stability of the system. Each 29-13 Signal Conditioner/Indicator is matched to the Flo-Tron Mass Flow Transmitter bearing the same serial number. Indicators and Transmitters should not be interchanged.

6.0 VISUAL INSPECTION

6.1 Check all fuel and electrical connections. If fuel leaks are detected, these must be corrected before proceeding with the test.

6.2 Check diesel fuel for clarity when bleeding the flowmeter to assure fresh fuel is being used for the test.

7.0 TEST ARTICLE PREPARATION

7.1 Secure all fuel connections. Heat exchanger must be used to assure proper fuel temperature control.

7.2 VENTING. To obtain accurate measurements it is important that there be no air or vapor in the flowmeter housing. The flowmeter and integral differential pressure transmitters are designed to be self-venting. When first starting the system the flowmeter should be bled through vent fittings on the housing and transmitter flanges. Bleeding should be continued until there is no indication of bubbles in the escaping liquid. Normally, once the system is bled as described previously, the unit can be started and stopped successively without rebleeding. If there is a chance of the system draining and/or air entering the flowmeter, it should be bled again.

8.0 TEST PROCEDURE

The fuel flow is measured during the last 5 minutes of each mode of the 13 mode diesel cycle. The Flo-Tron meter is used for all measurements excep Idle and 2 percent Load. These conditions are measured using the Cox Model 402 due to the inaccuracies of determining these low flow rates with the Flo-Tron meter.

Test Sequence	Test Description	Data Output
101	Turn on power to the indicator and LMF meter; allow at least 1/2 hour for warm-up. Bleed all entrapped air from the meter. (Ref. Para. 7.2). NOTE: DO NOT OPERATE THE METER WITHOUT LIQUID IN THE SYSTEM. Damage can result to the recirculating pump if it is operated dry.	
102	Zero readings should be checked and adjusted when installing the meter and at least once each day of operation. All flow readings will shift an amount equal to the zero offset. Reduce flow to zero by stopping the flow downstream of the LMF meter. THE LMF meter should be kept running with normal system pressure on the inlet. If the readout instrument does not zero, adjust the zero potentiometer until a zero reading is obtained. Adjust the "Low Zero Adjust" pot only. To "zero" the high range tramsmitter, repeat the procedure above while depressing the pushbutton marked "High Zero Check." For this adjustment, use the "High Zero Adjust" pot only. The system is now adjusted and ready for use. Experience will dictate how often it is necessary to check and/or readjust the zeros.	
103	Total Flow Counter: Flow in pounds of fuel will be accumulated by the counter continuously. The counter display will indicate the total accumulation as long as the toggle switch is in the "count" position. When switched to "Hold", the display will hold the accumulation at the instant of switching. When switched. back to "Count" mode, the display will show the latest total INCLUDING THE FLOW OCCURRING while the display was holding.	

8.0 TEST PROCEDURE (Continued)

Test Sequence	Test Description	Data Output
	To erase the total and start again from zero, press the "Reset" button. As soon as this button is released (if there is a flow) the counter will begin totalling again.	
104	Recirculating tank fuel can be introduced to the inlet of the tank. The flow meter will read a relatively high flow rate until the tank is filled to the proper level. The system can now be started.	
105	When the engine begins to use fuel, adjust the pressure regulator to 3 p.s.i.g.	
106	If a large, sudden change is made in flow rate, allow a few secnds for the flowmeter to stabilize before taking readings. If calibrating the flowmeter, allow enough tare weight on the calibrator for the flow to stabilize before the time cycle begins.	
107	To check zero on the flowmeter, turn the pressure regulator handle counter-clockwise until all load is removed. This will eliminate waiting for the float to shut the flow off completely. After the flow rate is resumed, adjust the pressure regulator to 3 p.s.i.g.	
108	Determine fuel flow rate in Lbs per unit time for each mode. Measurement is made for a minimum interval of 60 seconds.	Time Lbs.
109	Record fuel flow measurements in Lbs per hour.	Lbs/Hr.

9.0 DATA INPUT

All fuel flow measurements are entered on the data processing Form No. HD-751-01. Mass units should be consistent for each entry.

10.0 DATA ANALYSIS

None required.

11.0 DATA OUTPUT

Fuel mass inputs are used to calculate brake-specific emissions. These values are reported to test requester and maintained in the data file.

12.0 ACCEPTANCE CRITERIA

12.1 Fuel temperature must be maintained at 100 ± 10°F.

12.2 Adequate fuel pressure must be maintained per Manufacturer's specifications to insure proper operation of the engine.

13.0 QUALITY CONTROL PROVISIONS

13.1 Calibration is accomplished using a Flo-Tron Model 30 "dead weight" calibrator or equivalent. Calibration checks are performed monthly.

13.2 Fuel Flow measurements checked by Data Validation and compared to theoretical values supplied by manufacturer. Suspect values may require repetition of test.

EPA TEST PROCEDURE

Number TP-756

Page 1 of 4

SUBJECT FUEL FLOW MEASUREMENT - COX INSTRUMENT MODEL 402	
Reference	Data Form No. HD-751-01
Responsible Organization HEAVY DUTY ENGINE TESTING	Computer Program
Test Witness SUPERVISOR	Performance Interval EACH TEST
Type of Test Report COMPUTOR PROCESS FORM NO.	Supersedes NEW
Report Distribution CERTIFICATION, MANUFACTURER REPRESENTATIVE	Superseded by

REMARKS/COMMENTS

This procedure is used for fuel flow during the idle and 2 percent load conditions of Diesel Emission Tests.

ORIGINAL RELEASE APPROVALS

Office	Section	Signature	Date
Admin.	Quality Assurance		
Lab. Oper.	Chief		
HD Testing	Supervisor		

REVISIONS

Change Letter	Description of Change	Approval	Date

1.0 PURPOSE

This procedure describes the determination of fuel flow rates under steady state (equilibrium) conditions during the 13 mode diesel emission cycle. This procedure is used for the idle and 2 percent load conditions. Higher flow rates for the other modes are determined using the Flo-Tron meter (Procedure No. TP-755.)

2.0 TEST ARTICLE DESCRIPTION

The Cox Instrument Mode 402 is used primarily for the measurement of diesel fuel by actual measurement of the weight of fuel consumed per unit time.

3.0 REFERENCES

3.1 Cox Instruments - Manual for model 402 fuel measuring instrument.

4.0 REQUIRED EQUIPMENT/CONDITIONS

4.1 Diesel engine fuel system accessories as required. Additional fuel pump required by some engines.

4.2 Heat exchanger for maintaining proper fuel temperature (100± 10^{o}F.)

4.3 Electrical 110 volts. Shop air in excess of 60 p.s.i.g.

5.0 PRECAUTIONS

5.1 Instrument door must be kept closed during measurement to avoid air drafts which could interfere with the proper operation of the balance.

5.2 Care must be taken when engine is coming off a high power mode as a sudden surge of fuel may overflow the beaker.

6.0 VISUAL INSPECTION

6.1 Check condition of weights, look for scratches, dents, dust or spilled fuel before each test.

6.2 Check proper operation of the solenoid which trips the timer. Timer should trip at the balance point of the scale.

6.3 Assure unrestricted motion of the balance, and that fuel feed and return lines do not touch the fuel reservoir container.

7.0 TEST ARTICLE PREPARATION

7.1 Attach fuel feed, return and engine fuel lines to the instrument. Secure for leak tight operation.

7.2 Plug into 110 volt 60 #3 grounded (3 wire) receptacles.

7.3 Connect air supply to regulator and set pressure to 60 p.s.i.g.

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REVISIONS:	FUEL FLOW MEASUREMENT - COX INSTRUMENT MODEL 402	**PROCEDURE NO.** TP-756
	TEST PROCEDURE	**PAGE** 3 **OF** 4

8.0 TEST PROCEDURE

Test Sequence	Test Description	Data Output
101	The instrument has a capacity of three weights which can be operated electrically. The center weight is usually used for the amount of fuel to be measured. The other two may be used for tare weights if required. Place desired weight on the center bar lift arm. Lift arm must be in weight or down position.	Weight In Grams
102	Balance scale with tare weights as required. Scale should rest in balanced or center position of scale.	
103	Purge system with fuel until the fuel in the beaker is clear. Fresh fuel must be used for each test.	
104	Reset timer to zero and close instrument door.	
105	When engine is operating at equilibrium condition, trip center bar lift arm to remove weight, timer will start and stop automatically when scale returns to balanced condition Time intervals of at least 60 seconds should be used.	Time Seconds
106	Record fuel used in lbs. per hour.	Data Process Form Lbs./Hr.

9.0 DATA INPUT

Fuel measurement units must be compatible with program and consistent for each mode measured.

10.0 DATA ANALYSIS

None required.

11.0 DATA OUTPUT

Brake-specific emissions are calculated and reported as grams per hour and grams per brake horsepower hour. Data reported to test requester and maintained in data file.

12.0 ACCEPTANCE CRITERIA

12.1 Fuel temperature must be maintained between 90-110° F at pump inlet of the engine.

12.2 Fuel pressure must be maintained at manufacturer's specification for proper operation of the engine.

13.0 QUALITY CONTROL PROVISIONS

13.1 Temperatures, pressures and raw data checked by Data Validation. Entries suspected as being incorrect will require repetition of the test.

13.2 Instrument weight checked by Chemical Analysis section against NBS traceable standards at 6 month intervals, or when weights may have become damaged.

Section 800

DATA VALIDATION

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EPA TEST PROCEDURE

Number
TP-850

Page 1 of 5

SUBJECT
DATA VALIDATION - HEAVY DUTY DIESEL EMISSIONS

Reference	Data Form No.
Responsible Organization TEST OPERATIONS - HEAVY DUTY TESTING	Computer Program
Test Witness SUPERVISOR - HEAVY DUTY TESTING	Performance Interval EACH TEST
Type of Test Report	Supersedes NEW
Report Distribution TEST OPERATIONS - CERTIFICATION - QUALITY ASSURANCE	Superseded by

REMARKS/COMMENTS

ORIGINAL RELEASE APPROVALS

Office	Section	Signature	Date
Lab. Opera	Quality Assurance		
Lab. Branch	Chief		
HD Testing	Supervisor		

REVISIONS

Change Letter	Description of Change	Approval	Date

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1.0 PURPOSE

Data Validation establishes a control network to assure a smooth flow of all data collected during the performace of Heavy Duty engine emission tests. The Data Validation section will also check the data form to confirm the validity of the results and assure the data is within specified limits:

2.0 TEST ARTICLE DESCRIPTION

2.1 The following data sheets, chart traces and reports are required for a complete data validation system.

- Form HD-750-01 Check List, Buildup and Installation Diesel Test Engine
- Form HD-750-02 Receiving Inspection
- Form HD-750-03 Check List Test Cell 1 and 2 Diesel Engine Dynamometer Operation
- Form HD-750-04 Check List-Preparation of the Test Engine For Return to Manufacturer
- Form HD-750-05 Shipping Order
- Form HD-751-01 Data Sheet
- Recorder charts NDIR - CO and CO_2
- Recorder charts FID - HC
- Recorder chart - speed, smoke, torque

3.0 REFERENCES

3.1 "Quality Assurance Guidelines for Heavy Duty Mobile Emissions Measurement Systems" Section 6.5 Data Validation

4.0 REQUIRED EQUIPMENT

4.1 Validation stamps

5.0 PRECAUTIONS

Not applicable

6.0 VISUAL INSPECTION

6.1 Contained in Section 8.0.

7.0 TEST ARTICLE PREPARATION

7.1 All forms and traces must be complete before submittal to Data Validation.

REVISIONS:	DATA VALIDATION - HEAVY DUTY DIESEL EMISSIONS TEST PROCEDURE	PROCEDURE NO. TP-850 PAGE 4 OF 5

8.0 TEST PROCEDURE

There is presently no formal method established for conducting data validation of the heavy duty test data. Validation is presently being accomplished by the Supervisor and Team Leader with concurrence from Certification. There is a need for establishing Data Validation Procedures independent of the test group as is presently being done for Light Duty Testing. (TP-801)

It is recommended that separate forms be used for the smoke and gaseous test. Check sheets should be signed and witnessed and procedures developed for quickly determining the validity of speed/time/torque traces.

Analyzer traces should be checked and compared with computer outputs.

Instrument checks should be visually checked for corrections.

A procedure for data validation should be constructed according to the EPA requirements of paper flow and data reporting with appropriate check points from receiving inspection testing through return of the engine to manufacturer.

9.0 DATA INPUT

9.1 This information is contained in Section 8.0.

10.0 DATA ANALYSIS

10.1 Analysis is performed by the Data Branch using the following computer program.

11.0 DATA OUTPUT

Validated data is returned to Heavy Duty Supervisor for distribution.

12.0 ACCEPTANCE CRITERIA

12.1 Refer to table in Introduction or individual test procedures.

13.0 QUALITY PROVISIONS

13.1 The Q.A. Department should audit final results to assure all entries and results are within acceptable limits.

13.2 A statistical inference study should also be made of typical problems and solutions from data compiled in the data bank of previous test results. This study can be performed by using control charts, analysis of variance, and error analysis techniques.

Section 900

PROGRAM PLANNING AND QUALITY AUDIT

Currently no procedures are included in this Section of the manual. Those procedures pertaining to this Section must be supplied by the user and may be supplied by the EPA in subsequent revisions.

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